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JULY, 1944.

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JACKSONIAN PRIZE.

THE Council of the Royal Australasian College of Surgeons has been advised by the Council of the Royal College of Surgeons of England that the subject chosen for the Jacksonian Prize for the year 1945 is as follows: "Bone Grafting in Surgery: Its Indications, Methods and Results." Full details governing the conditions of the prize may be obtained from the Secretary of the Royal Australasian College of Surgeons, Spring Street, Melbourne, C.1.

Editorial Notices.

ALL articles submitted for publication in this journal must be typewritten and double or treble spacing should be used. Each article should conclude with a brief summary and statement of conclusions. Authors are requested to avoid the use of abbreviations and not to underline either words or phrases.

Authors are requested to submit two typescript copies of all articles.

References to articles and books should be carefully checked. In a reference the following information should be given without any abbreviation: initials of author, surname of author, full title of article, name of journal, volume, full date (month, day and year), number of the first page of the article. If a reference is made to an abstract of a paper, the name of the original journal, together with that of the journal in which the abstract has appeared, should be given, with full date in each instance.

When illustrations are required, good photographic prints on glossy gaslight paper should be submitted. Line drawings, charts, graphs and so forth should be drawn on thick white paper in indian ink. Authors who are not accustomed to prepare drawings of this kind, are invited to seek the advice of the Editor if they are in any doubt as to the correct procedure. Skiagrams can be reproduced satisfactorily only if good prints or negatives are available.

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THE AUSTRALIAN AND NEW ZEALAND JOURNAL OF SURGERY

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A RATIONAL TREATMENT OF GUNSHOT WOUNDS OF LONG BONES WITH ESTABLISHED SEPSIS.[1]

By HARLEY TURNBULL,
Major, Australian Army Medical Corps.

SURGICAL treatment of established sepsis is subject to fashion. Methods wax and wane in popularity, showing that the ideal technique has not been found. Some are unsound physiologically; others are capable of improvement. Over a period of years the surgery of infected gunshot wounds has been dominated by the ritual prevailing at the time. Early in the Great War, 1914-1918, strong antiseptics held sway; later the method of Carrel-Dakin was used, and at the end the technique of Winnett-Orr. The fashion of Winnett-Orr has prevailed until this time. It has been popularized by Trueta, but Trueta's is not a new technique in treatment and all credit should be given to Winnett-Orr. The closed plaster technique appears at present to be the universally adopted form of treatment for gunshot wounds involving the long bones. It is an improvement over other methods and is a definite step forward, but it is not by any means the answer to the prayer of the surgeon who has to treat patients with established bone sepsis. Closer plaster technique has a definite place in treatment, but its place is strictly limited. It should be used only under two conditions: (*a*) for recent gunshot wounds in which established bone sepsis has not occurred, (*b*) for purposes of transport.

In recent battle casualties the treatment is now standardized: complete excision of the wound, adequate drainage, instillation of sulphanilamide, light packing with "Vaseline" gauze, and immobilization in plaster. This treatment will in the majority of cases prevent the onset of established sepsis; if sepsis does not occur, then the closed plaster technique must be continued, for its advantages are many. It limits inquisitive inspection of the wound and prevents secondary infection; it is comfortable; the rest associated with it encourages broken bones and damaged tissues to mend; it prevents lymphatic and venous stasis, thereby accelerating the normal process of repair; and it saves work for both nursing and surgical staffs.

In the transport of patients plaster immobilization is the fulfilment of the surgeon's dream. It is comfortable, it prevents shock, it allows ease of handling, and in many cases it is the only method by which a patient can be moved with safety. When the patient finally arrives at a base hospital where his prolonged treatment is to be undertaken, a review of his case must be made. If bone sepsis has become established, then the closed plaster technique must be abandoned, for there is little or no place in a base hospital for the treatment of established bone sepsis by closed plaster.

[1] Accepted for publication on April 19, 1944.

A ward containing numbers of patients who have gunshot wounds of long bones with established sepsis treated in closed plaster is a tragic and depressing sight. It needs to be seen only once and the image will persist for ever. Its setting is pre-Listerian and its atmosphere one of futility and hopelessness. Every base hospital has these pitiable results of war; the patients go on month after month feebly fighting their way towards finalization by sudden death from secondary hæmorrhage, by a lingering death from chronic sepsis, by amputation after many months which in itself is a confession of failure, or lastly by resolution and repair with varying degrees of dysfunction. Their existence is pitiable, their morale has long since gone, they are weak caricatures of the men they once were. They are emotional and unstable, they often cry but never laugh, they whine and are intolerant, they are a group of broken and defeated men. The stench of the ward is appalling and the patients themselves stink. They are a constant trial to the surgeon and nursing staff. Closed plaster must not be used in these cases, for it is productive only of harm. It is these patients who are suitable for treatment by antisepsis.

PRINCIPLES IN THE TREATMENT OF BONE SEPSIS.

Irrespective of whatever form of treatment is adopted, there are certain principles which must be rigidly adhered to if treatment is to be a success. These principles are both general and local and both factors are of the utmost importance. If the general condition of the patient is not restored to normal, then it is equally impossible to expect any healing in the part affected, for if general treatment fails, local treatment will fail likewise. The complete treatment can be briefly summarized under the following headings:

1. *General*:
   - (*a*) Blood chemistry.
   - (*b*) Diet.
   - (*c*) Mental rehabilitation: (i) encouragement, (ii) diversional therapy, (iii) physiotherapy.
2. *Local*:
   - (*a*) Immobilization.
   - (*b*) Drainage.
   - (*c*) Removal of sequestra.
   - (*d*) Control of infection.

General Treatment.

The Blood.—The chemical constitution of the blood becomes grossly deranged. Loss of protein from the persistent copious discharge of pus is intense. Sepsis and loss of protein cause a progressive fall in the hæmoglobin value, as well as in the red cell count, and a marked anæmia results. There must be a constant check on the blood by blood counts done at weekly or fortnightly intervals and repeated blood transfusions may need to be given to keep the blood picture normal.

Diet.—A diet with a high caloric value consisting of a high protein and carbohydrate index and moderate fat is essential. Vitamins in abundance are necessary, particularly vitamin *C* in the form of ascorbic acid.

Mental Treatment.—These long drawn out cases become ultimately a psychiatric as well as a physical problem. Morale has gone, a defeatist attitude is adopted, the patients are emotional, cry and have an intense dislike of being touched. Washing and the preservation of an intact skin on pressure points are a torture. The patients are unreasonable in their attitude, and the desire to recover has gone.

The first thing is to make these men believe in themselves. Remove closed plasters with their all-pervading stench. Institute dressings and let the patients see that something is being done for them. Make their surroundings clean and make the men themselves clean. Encourage them, give them diversional therapy to relieve the boredom and shorten the hours, and in short compel confidence in self. Physiotherapy must be continued throughout treatment. Massage and exercise of unaffected limbs are necessary, as are movement of joints and massage of the affected limb to the fullest extent possible.

Local Treatment.

Immobilization.—Immobilization must be obtained by a bent Thomas splint with weight extension and the use of a Balkan frame for injuries of the lower limb. A Thomas splint gives comfortable immobilization, ease in attention and facility in dressings. A very useful method is to apply strapping to the limb and enclose the limb below the fracture in plaster covering the strapping or to apply the strapping and enclose the limb with an Unna's bandage. Similar principles are required for compound fractures of the upper limb or for other regions. A certain amount of ingenuity is often necessary to get things correctly adjusted and comfortable.

Drainage.—The first step in local treatment is to provide free drainage which must be adequate and complete. If this step is neglected treatment will fail, for pocketing of pus and gravitational abscesses will result. Dependent drainage is imperative. If the wound is anterior and the sinus ends deeply and blindly, then an incision must be made posteriorly to allow the direct drainage of pus. Once free drainage is established it must be kept free until sepsis is controlled and resolution of bone occurs.

Sequestra.—Profuse pus usually means dead bone, and dead bone demands prompt removal. A constant check by X-ray examination is made at regular intervals, usually once a month, for sequestra in these cases separate quickly and easily, much more so than is generally recognized. It is not necessary to give an anæsthetic in all cases for removal of sequestra as, if small, they can often be removed comfortably and painlessly with sinus forceps during routine dressings. If an anæsthetic is necessary, "Pentothal" is the ideal agent. Before the removal of sequestra of any size which would involve opening tissue planes is contemplated, some pre-operative measures are imperative. These cases are notorious for an acute flare up with the development of a local streptococcal infection, usually in the nature of an erysipelas or cellulitis with lymphadenitis. Before a radical sequestrectomy is performed adequate dosage with a sulphonamide derivative should be given for twenty-four hours preceding operation and continued post-operatively. If a local reaction does occur, ultra-violet radiation is almost specific when given in graduated doses.

Control of Infection.—Control of infection is the crux of the whole question. Surgical sterility does not necessarily mean bacteriological sterility. Wounds may have little discharge and will heal, yet grow copious cultures of pathogenic organisms. This means that a wound does not have to be sterile on culture for healing to occur. Sterility cannot be achieved in infected wounds by any known form of antisepsis while at the same time the tissue cells remain uninjured. The aim in infected wounds is not to achieve bacteriological sterility, but to keep pathogenic flora down to a minimum, to diminish protein loss and to make the condition of wounds such that natural healing occurs. Closed plaster cannot achieve this. It does not diminish established infection, it does not diminish exudate, but it does provide a very fruitful nidus for growth of organisms. Despite statements to the contrary, there are no virtuous properties of healing in exudate from wounds. Exudate

is a secretion, the product of a harmful process due to infection; it must be got rid of, and the dressings of a wound with its closed plaster is not the place in which it should remain. Saturated dressings and a saturated stinking plaster are ideal culture media in which organisms can and do grow.

Surgical sterility, as defined above, can be achieved by the use of one or other of the acridine antiseptics, the best of which is 5 amino-acridine hydrochloride. This 5 amino-acridine is not the perfect antiseptic, but it is the best as yet that we have at our disposal. It does produce results, for wounds become clean and heal, and it is healing wounds alone that are our concern and object.

PROPERTIES OF 5 AMINO-ACRIDINE HYDROCHLORIDE.

The antiseptic 5 amino-acridine hydrochloride has a pH value of 6; it inhibits growth of pathogenic organisms; it is bactericidal mainly to streptococci, less to *Staphylococcus aureus* and *Bacillus coli*, still less to *Bacillus proteus* and has no action on *Bacillus pyocyaneus*. It remains fully active in the presence of serum proteins and pus. It is active in extreme dilution and clinically is non-irritating to tissues when in solution of one in 1,000. It is non-staining, a fact of importance to nursing staff and laundry. In the powder form it is irritating and will cause a superficial tissue necrosis, so should be used in this form only very occasionally in a grossly infected wound, in an abscess cavity after incision, in an abscess cavity in bone, or in a wound after removal of sequestra. In recent wounds it can be used with sulphanilamide in the proportion of one part in ten of sulphanilamide as they are compatible and the bacteriostatic action of the latter is reinforced by the antiseptic action of the acridine.

FLORA OF INFECTED WOUNDS.

The bacterial flora found associated with chronic bone sepsis consists of hæmolytic streptococcus, *Staphylococcus aureus*, *Bacillus pyocyaneus*, *Bacillus proteus*, *Bacillus coli* and diphtheroids. The big three are the streptococcus, hæmolytic *Staphylococcus aureus* and *Bacillus pyocyaneus*. It is these three virulent organisms that cause most damage, prevent healing, prolong morbidity and increase mortality. Control these three, and surgical sterility will result, allowing healing to occur.

5 amino-acridine has a potent effect on the hæmolytic streptococcus and a less but appreciable effect on hæmolytic *Staphylococcus aureus*. The most suitable strength for use in wounds is one in 1,000 solution. In this dilution it is neutral in reaction and does not damage the tissues. Used full strength as a powder, it will completely sterilize an infected wound of all organisms and yield a sterile culture, but in this strength it is irritating and will cause a surface tissue necrosis. A strength of one in 1,000 is a happy medium which will achieve its effect without damage to cells. Stronger solutions have been tried, but possess no special virtue, and produce an outpouring of lymph and some necrosis.

When *Bacillus pyocyaneus* appears in established bone sepsis, which it certainly will do, one must be prepared to ring the changes. 5 amino-acridine is compatible with acetic acid, and 2% acetic acid must be added to the one in 1,000 solution being used. The 2% acetic acid changes the reaction of one in 1,000 5 amino-acridine solution, which in itself is neutral. This change in acidity is noticed by the patient, who complains of a slightly irritating effect, but it causes no discomfort. When its use is continued for several days, it will cause a slight excoriation around the wound edge. If this occurs, sterile zinc cream smeared over the area will alleviate the irritability.

If this treatment is persisted with, a state approaching surgical sterility will result and a healing wound be the reward.

ACTIONS OF 5 AMINO-ACRIDINE.

Local Effects.

When 5 amino-acridine is used alone or in combination with 2% acetic acid, the clinical results may be summarized as: (*a*) diminution in discharge and fœtor, (*b*) healthy appearance of the wound, (*c*) absence of heaping or flabby granulations, (*d*) healthy appearance of the surrounding skin and limb as a whole, (*e*) absence of œdema in limb.

General Effects.

The general effects are as follows: (*a*) a progressive rise in the red blood cells and hæmoglobin, (*b*) a general well-being, (*c*) increased appetite, (*d*) increase in weight.

These are the clinical signs of improvement which will occur, provided the first axiom in treatment is observed; that is, all sequestra must have been removed and all pus pockets given free drainage.

In respect of the blood picture one interesting fact has been observed, namely, the red cell count will come up to normal figures, the hæmoglobin value will approach its normal level, but the white cell count remains high and is constantly in the region of 12,000 to 15,000 cells per cubic millimetre.

A second point of interest is that cultures of the wound appear to be influenced by the weather. In cold spells the bacterial flora as evidenced by cultures appear to increase, especially streptococci, and subside with warm weather, only to reappear when another cold snap occurs.

TECHNIQUE IN THE DRESSING OF WOUNDS.

In any ward where multiple dressings have to be done the bugbear is cross-infection and contamination. Even when the most strict aseptic precautions are taken, cross-infection will occur, and it is beyond the bounds of human endeavour to control it. The aim is to try to eliminate it and by so doing to reduce it to a minimum. The three main channels by which cross-infection is established are: (*a*) oral infection from patients or dressers, (*b*) air-borne infection, (*c*) a break in asepsis.

It is the duty of all who are concerned with these battle casualties to try to eliminate it, and in order to reduce cross-infection a rigid ward and dressing technique must be observed.

Ward Technique.—The ward technique may be summarized as follows: (*a*) breakfast is given, the ward is cleaned, beds are made; (*b*) all patients not having dressings leave the ward; (*c*) the ward is closed for thirty minutes to allow dust to settle; (*d*) no talking, no diversional therapy or physiotherapy is allowed; (*e*) no unnecessary activity takes place; (*f*) only those persons indispensable to the ward are permitted to enter.

Dressing Technique.—The dressing technique is as follows:

1. The patient being dressed wears a mask. Dressers all wear masks covering nose and mouth.

2. Three sisters do the dressings, having scrubbed their hands in soap and water only. The first sister exposes the area to be dressed and tidies the bed after dressing; she also sterilizes used instruments. The second sister hands out sterile dressings and articles required, and opens receptacle for soiled dressings. The third sister dresses the wound, using sterile instruments only. The first sister prepares the next patient while a dressing is being done.

3. Sterile towels are to be used to isolate the affected part.

4. With a little organization and good team work all dressings can be completed efficiently and expeditiously.

TECHNIQUE OF THE LOCAL TREATMENT OF BONE SEPSIS.

The technique of the local treatment of bone sepsis depends on the condition of the bone—first of all whether sequestra are present, and secondly whether sequestra are forming or absent, and in these circumstances whether gross sepsis or mild sepsis is present.

Treatment when Sequestra are Present.

When sequestra are present, restore the blood picture to normal by transfusion. For twenty-four hours prior to operation give a full dosage of one of the sulphonamides by mouth. Induce anæsthesia by "Pentothal". Remove the sequestra, open up all blind pockets, provide dependent drainage by counter-incision and take a swabbing for culture, effect hæmostasis and control oozing as far as possible. Pour into the wound up to ten grammes of a powder consisting of 5 amino-acridine and sulphanilamide in the proportion of one part of 5 amino-acridine to ten of sulphanilamide. Rub this powder into all parts of the wound and around the bone fragments, pack lightly with "Vaseline" gauze and bandage. Replace on a bent Thomas splint if the femur is involved, and provide a point of purchase for extension either by strapping or a Kirschner wire through the tibial tubercle. Leave the wound occluded for from five to seven days, then remove the "Vaseline" gauze, take a swabbing and institute irrigation as would be done if sequestra were absent.

Treatment when Sequestra are Forming or Absent.

When sequestra are forming or are absent, treat by irrigation with a one in 1,000 solution of the chosen acridine.

In the Presence of Gross Sepsis.—In the presence of gross sepsis introduce a small rubber tube, size 8 French catheter, into each sinus. Two or three small lateral holes should be cut in the tube close to the tip. Pack a little "Vaseline" gauze lightly around the exit of each tube from the sinus. Smear 5 amino-acridine greaseless ointment (see appendix) over the surrounding skin and cover with large sterile pads. Connect each tube up to its own "Soluvac" bottle containing the 5 amino-acridine solution; the drip should be stabilized at six to eight drops to the minute. It is most important that each sinus should possess its own complete unit of "Soluvac" bottle and tube. Such an arrangement ensures that each sinus will receive the amount of solution in its bottle. If the tubes are connected in continuity with one bottle after the method of Carrel-Dakin, it is an absolute certainty that some will get all the solution and others none. Likewise it is important that the solution should not drop at a rate greater than six to eight drops to the minute; this rate will make it sure that an adequate amount will enter the sinuses and will prevent saturation of the dressings and bed clothing. Absorption by the tissue cells surrounding the sinus, evaporation due to body heat and atmospheric conditions will prevent overflow.

The drip should be continuous and the wounds not touched for two days. They are then inspected and the tubes are removed. Culture tubes are incubated from skin and sinuses. The sinuses are syringed out freely with normal saline solution, the tubes, which have been cleaned and boiled, are reinserted, and the procedure is carried out as above. This continuous irrigation is carried on until the vicious circle of sepsis has been broken. The evidence of this is: (i) Wounds are cleaner and discharge less. (ii) Cultures are not so readily obtained. (iii) The local condition of the limb is healthier. (iv) An improvement in the general condition occurs. When this state is reached, the continuous irrigation is replaced by intermittent irrigation and the procedure is as for mild sepsis.

In the Presence of Mild Sepsis.—In the presence of mild sepsis the only change in technique is that the irrigation is intermittent. The solution runs for four hours at a faster rate of fifteen to twenty drops to the minute. At the end of four hours' irrigation the tubes are removed and the sinuses are filled with 5 amino-acridine emulsion (see appendix). "Vaseline" gauze is lightly packed into the sinus openings and the wound is occluded with sterile dressings for two days, when they are again taken down, cultures are made, tubes are reinserted and irrigation is completed.

TYPES OF CASES SUITABLE FOR IRRIGATION.

Types of cases in which irrigation may be used include gross gunshot wounds of the extremities involving either long bones or joints with established sepsis.

Upper Extremity.

Humerus.—Gunshot wounds of the humerus treated by an abduction spica or hanging plaster cast become foul, œdematous, and sooner or later uncomfortable. Œdema is never an aid to healing, and the sooner it is relieved, the better. In the irrigation method a Kirschner wire is inserted through the olecranon, a stirrup is attached, the arm is slung up to a Balkan frame, tubes are inserted and irrigation is commenced. Gravity is thus coopted as an aid to healing.

Forearm.—Gunshot wounds of the forearm are best treated by the closed plaster of Paris technique, unless gross sepsis becomes established.

Lower Extremity.

In most cases of gunshot wounds of the lower extremity a bent Thomas splint gives the best support.

Hip Joint or Pelvis.—In gunshot wounds of the hip joint or pelvis irrigation is used.

Femur.—In gunshot wounds of the femur retention by a Kirschner wire through the tibial tubercle or strapping, traction and irrigation are used.

Knee Joint.—In gunshot wounds of the knee joint a wire is put through the *os calcis* or strapping is applied, and traction and irrigation are used.

Tibia.—In gunshot wounds of the tibia a wire is inserted through the *os calcis*, and traction and irrigation are used.

Ankle Joint and Foot.—In gunshot wounds of the ankle and foot a foot-piece is applied and traction and irrigation are used. When the bone infection has been conquered and healing is occurring, then ordinary methods of treatment are adopted. These are either secondary suture or the various plastic procedures of skin grafting—by the pinch or Thiersch, full thickness or crossed-leg flap method—and retention when applicable by plaster until bony union is sound.

Results Achieved by this Method.

Some of the improvement from this method is due to the mechanical action of cleansing by irrigation. This fact is undoubted and indisputable. At the commencement of this investigation eusol was the first solution used. There was an immediate improvement which was not marked but quite evident both in the general condition of the patient and the local condition of the limb, but it did not control the bacterial flora, which increased both in variety and quantity. It did not diminish pus formation to any extent and granulation tissue was flabby and redundant. At the end of a month the change was made to 5 amino-acridine.

USE OF THE ACRIDINES.

At this stage a brief survey of the acridine substances is given with reasons for and against their use and why 5 amino-acridine was chosen.

Although 5 amino-acridine hydrochloride was selected as the best of these compounds, use has been made of others of this series.

Proflavine Base.—Proflavine base has a pH of 8, but a solubility of only one in 3,000, so is unsuitable for use except as a powder. It stains everything with which it comes in contact; its use is not recommended.

Proflavine.—Proflavine B.P. (2-8 diamino-acridine) has a solubility of one in 40 to one in 300. This is actually the acid bisulphate with a pH of 2, so produces an escharotic effect on the tissues if used as the powder. It is also irritating and causes some superficial necrosis if used in a one in 1,000 solution, unless it is neutralized by one-quarter of its weight of sodium bicarbonate, which brings the pH to 6. This neutralized solution gives very good results, but it stains everything badly. Its use as a powder is not advised as a routine.

Acriflavine.—Acriflavine is an acid hydrochloride of unstable composition and has a pH of 2, so is very irritating to the tissues and it also stains everything. It has been popularized because of its low solubility (one in three). Its further use should be abandoned in favour of neutralized proflavine, 5 amino-acridine or 2-7 diamino-acridine.

Proflavine Benzoate.—Trials of proflavine benzoate are being carried out, but there is not sufficient clinical evidence as yet to evaluate results.

2-7 *Diamino-Acridine.*—2-7 diamino-acridine has a pH of 6; it is non-irritating to the tissues in solution and produces just as good results as 5 amino-acridine, but it has almost a blood-red colour and stains badly.

5 *Amino-Acridine.*—The properties and virtues of 5 amino-acridine have already been referred to and the results mentioned in this paper have been obtained with this member of the acridine series. The fact that it is stainless weighs greatly with the nursing staff and the laundry.

The use of acridine antiseptics is of inestimable value when there are sulphonamide-resistant organisms in wounds.

Recent investigations by Albert show that although surgical gauze absorbs relatively large amounts of the acridine, it is not fixed, but will come into solution in the body fluids, so that it is quite effective if used as a moist dressing on wounds as occasion demands.

1. The Powder. In some cases in which sequestra had to be removed 5 amino-acridine powder was used. This will change a wound that is full of pus and teeming with bacteria in the space of forty-eight hours into a wound that is bacteriologically sterile, provided sequestra are removed and drainage is dependent. However, in powder form it does cause some superficial tissue necrosis which is not marked but quite evident. A lymph coagulum forms a film over the wound, but clears after a few days' irrigation.

When sequestra are removed or abscesses drained, the powder should always be used, but only in combination with sulphanilamide in varying strengths of one in 10 to one in 20—that is, one of 5 amino-acridine to 10 of sulphanilamide—the strength depending on the tissue and amount of sepsis.

It is inadvisable to use any of the acridines in pure powder form, but if the powder is used only the one application should be made. The powder must be applied over the whole surface of the wound and rubbed in lightly. Apply a "Vaseline" gauze dressing and leave for five to seven days, then institute irrigation. In order of preference the best powders to use are 5 amino-acridine, 2-7 diamino-acridine, proflavine benzoate, and proflavine

base. Use of proflavine B.P. is not recommended for the reasons already stated, but if other acridines are not available, one application in a grossly septic wound according to the technique of Mitchell and Buttle may be permissible.

2. The Solution. At first irrigation was commenced with a one in 1,500 solution of 5 amino-acridine. This was innocuous to the tissues and had a decided effect on the bacterial flora. After several weeks the strength was increased to one in 1,000 and later to one in 500. The one in 500 solution was slightly irritating and caused slight superficial necrosis with aggregations of lymph in wound sinuses. The one in 1,000 solution was finally selected as the most suitable dilution for use. This strength of solution is also advised for other acridines, but if proflavine B.P. is used it must always be neutralized as already advised by the addition of one-fourth its weight of sodium bicarbonate.

GENERAL SUMMARY.

The results achieved by 5 amino-acridine have been listed earlier in this article, but the following general statements provide a useful summary.

Blood Picture.

After the institution of this treatment not one patient required a blood transfusion to restore blood normality. From the commencement the blood rose naturally in a slow progressive curve until the blood picture was normal. The only abnormality noticed was a persistent, moderately high white cell count, mainly polymorphonuclear cells, in the region of 12,000 or so per cubic millimetre. The explanation of this is quite evident in that whilst sepsis and toxæmia had been largely controlled, bacteriological sterility was not obtained and sufficient absorption was occurring to stimulate a normal leucocytosis. It is a fact that prior to acridine irrigation the blood counts progressively fell week by week so that repeated blood transfusions were compulsory. As soon as irrigation was commenced the reverse occurred. The blood counts progressively rose and not a single blood transfusion was required or given. This single fact alone speaks for itself.

General Health.

The improvement was amazing. Appetite improved and those very ill immediately commenced to put on weight. A very potent adjunct to the irrigation treatment in this respect was of course the high caloric diet instituted, rich in proteins, carbohydrates and vitamins, particularly vitamin *C*.

Mental Condition.

Some of the patients before the institution of treatment had developed a pronounced psychotic phase. This disappeared gradually, and when treatment was combined with diversional therapy and physiotherapy, mental balance and a sense of normality returned. Sedatives and anodynes were used less and less and were finally discontinued.

Local Condition of the Limb.

The skin regained its colour and the tissues their tone. In not one single case after the institution of irrigation with 5 amino-acridine was there a secondary hæmorrhage. This means in simple language that progress of the infective process was halted. Previous to this form of treatment secondary hæmorrhages with their tragic, unexpected suddenness did occur. A secondary hæmorrhage can occur only when the vessel has become involved in the

infective process with resultant softening of the vessel wall which gives way. The fact that secondary hæmorrhage did not occur speaks volumes for the condition of the tissues in the depths of the wound with the acridine irrigation.

Bacterial Flora.

Bacteriological sterility was not and could not be attained, but growth was vastly diminished. A particular organism would disappear from the culture for several examinations and then would suddenly reappear for no particular reason. Hæmolytic streptococci were practically eliminated from the wounds, but not entirely, and a few would crop up every now and again. An appreciable but lesser effect was noticed on *Staphylococcus aureus*, *Bacillus pyocyaneus* and *Bacillus proteus*. These would disappear, only to reappear at frequent intervals, but in diminishing numbers.

Healing.

Healing was undoubtedly hastened. As the bacterial flora diminished and exudate became less, the general condition improved and healing was quickened. Despite the fact that sinuses healed, cultures up to the last few days showed pathogenic organisms. This proves the fact that surgical sterility does not mean bacteriological sterility, and healing can occur in the presence of some sepsis. This is evidence also of the well established fact that reopening of these wounds should not be treated lightly. A long interval of time should elapse before any reconstructive surgery is done on these limbs. It is certain that although normal healing has occurred, pathogenic organisms still abound in the deeper tissues and will flare up into active sepsis again if disturbed too early. Any reconstruction which will involve opening up tissue planes should consequently be deferred for a reasonable period until the natural resistance of the body has overcome such organisms as remain. When reconstruction is done a full pre-operative and post-operative course of one of the sulphonamide drugs should be given.

Ward Surroundings.

A few words under the heading of ward surroundings must be included. These patients require very firm, but fair and humane, handling. To be firm is not to be callous, and sympathy must never become evident by word. Sympathy is made manifest by the attention given. The slightest complaint, however trivial, must be investigated, whether it is in relation to the splint, the limb or other matters. If the complaint is just, then it is corrected. If the complaint is unfounded and unreasonable, the patient must never be allowed to get away with it and a few well chosen words will once and for all lessen a weight which may readily become unbearable. A life without faith is empty, and these men must be given a faith; that credo is, first, faith in themselves, second, faith in those who treat them and, third, faith that they are going to get well and that, despite their residual infirmities, life is still good. These men confined to long months in bed become lazy and their vegetative existence must be changed to one of mental activity. The physiotherapist will do her job of necessity, but push the diversional therapy to the extreme so that the long hours will be shortened.

Cleanliness in the ward and surroundings is paramount; flowers add a charm and grace that are positive and tangible—little things perhaps, but bigger things to these men whose treatment is prolonged through many dreary days.

As soon as the condition of the limb progresses, get the patients out of bed in their Thomas splints with fixed traction, put them in wheel chairs and

let them get about, send them down to the entertainment hall, give them motor car rides. It is another stage in their progress onward to finalization and the goal upon which their eyes are ever fixed.

ACKNOWLEDGEMENTS.

My thanks are given to Bayer Pharma Limited, who manufacture 5 amino-acridine hydrochloride in Sydney under the trade name of "Monacrin", and whose generosity in supplying the powder enabled this work to be done; to Group-Captain Hugh Poate for his unfailing stimulus, encouragement and advice; to Lieutenant-Colonel Starr for his helpful criticism; to Dr. Adrien Albert, whose knowledge of the acridines is profound; to Major Florence Voss, who did innumerable wound cultures and blood counts; to the nursing staff for their zeal and loyalty; to Colonel W. Wood, commanding officer of the hospital; and finally to the Director-General of Medical Services, by whose permission this paper is published.

APPENDIX.

5 Amino-Acridine Emulsion.

Olei Olivæ or *Olei Arachis*	50%
Liquoris Calcii Hydroxidi Saccharati (B.P.C.)	5%
Aquæ Distillatæ	45%
5 Amino-Acridini	0·05%

This makes a 1-1,000 strength emulsion.

5 Amino-Acridine Greaseless Ointment.

5 Amino-Acridini	0·1%
Pulvis Amyli	1·5%
Pulvis Tragacanthæ Compositi ..	1·5%
Glycerini	50%
Aquæ Distillatæ	*ad* 100

PLASTIC PRINCIPLES IN COMMON SURGICAL PROCEDURES.[1]

By B. K. Rank,

Major, Australian Army Medical Corps; Facio-Maxillary and Plastic Surgery Unit at Heidelberg Military Hospital.

With the increasing trend towards specialization in surgical practice, we must never forget that no specialty can be a self-contained entity. There are arbitrary divisions—some regional, some systematic, some elaborated about a particular form of diagnosis or special indication of treatment; but, in any case, without rigid demarcation of where they start or finish. We must not forget also that no specialty means anything except in its correct orientation as part and parcel of the whole gamut of surgery.

The pros and cons of specialism may be open to argument, but we cannot deny the advantages of accumulated experience and skill attained by attention focused on a preselected group of cases. These advantages, however, are only half attained in developing the particular specialty, for every branch of surgery owes something to the general fund and to teaching as it affects the whole of surgery. Every specialist owes something to the common "set-up" which permits of his being a specialist.

Plastic surgery, which deals with reconstructive processes, is regarded by many in many countries as a highly specialized branch of surgery. I believe it is an integral part of all surgery, and that it becomes specialized only when numbers of its more difficult problems are large. Thus it does become a specialty with the destruction and mutilation of war-time, with which, in fact, its development has always been so closely associated. So too any modern city of size, from its accidents of high-speed industry and transport, from its disease processes and their treatment, and from its congenitally maimed, presents ample difficult problems for and expectations of surgical reconstruction.

If, then, in these circumstances plastic surgery is a specialty, we too have a teaching duty to all surgeons. This can be dissected in three directions:

1. First to teach the field of plastic work, common ground to all surgeons, which all must realize and apply in full. Certain problems of trauma, such as a large area of skin loss, the final treatment of minor face injuries, or the primary treatment of any face injury, must inevitably be treated by the general surgeon. It is no boast of the specialist to expect to lead the teaching of the correct treatment in these conditions by declaring the experience of his many mistakes over hundreds of cases—mistakes far more numerous than the occasional user of his methods can afford.

2. Secondly, there is a field of knowledge which has accumulated in the specialty by pruning and cultivation, often from empirical seeds. Much of this is now rationalized by use and firmly established in the various manœuvres of plastic work, no longer on a trial and error basis. Some of this knowledge, if correctly understood and applied, might well increase the scope or effectiveness of surgeons in diverse directions. The order of atraumatic technique (for example, finer instruments), essentially established and well proven in plastic work, might with advantage be extended to cover all surgical practice.

[1] Read in Hobart at the annual meeting of Tasmanian Fellows of the Royal Australasian College of Surgeons, September, 1943. Accepted for publication on March 6, 1944.

3. Thirdly, all surgeons must know something of the scope, the developments and the possibilities of reconstructive work; moreover, its limitations. This, for two reasons, apart from mutual interest and curiosity: (*a*) for its bearing on certain indications of primary treatment, (*b*) for the obligation to our patient of knowing what constitutes a satisfactory or optimum end-result under the best modern conditions.

I intend now to cover some phases in each of these three directions.

RECOGNITION AND MANAGEMENT OF SKIN LOSS.

The problem of the recognition and management of skin loss enters the field of all. It may arise after injury or surgical excisions in any part of the body, from a traumatic avulsion of the scalp to a skin excision for disease on the sole of the foot.

We have been well schooled in the management of soft tissue injuries without or with negligible skin loss: the importance of *débridement* rather

FIGURE IA. Melanoma on lower eyelid increasing in size and causing irritation of the eye lashes.

FIGURE IB. Three weeks after wide excision of the lesion shown in Figure IA and application of a primary thick split skin graft. The graft makes possible the wide excision indicated by the condition and primary closure without tension on a vulnerable area.

than of antisepsis; wound excision when indicated; the importance of immobilization; the indications and contraindications for primary or secondary suture. But this is only half the story of soft tissue injuries, as it does not cater for the wound with tissue loss, which for practical purposes means skin loss; for skin is the vulnerable tissue, and a wound is healed when the skin is healed.

We must get into the habit of taking a broad view and think not of primary and secondary suture of a wound, but of primary and secondary closure of a wound. This may, perchance, be by suture if there is no skin loss; but never lose sight of the equally important indication and place for primary and secondary skin grafting of the wound with skin loss. We must always look for and assess what is compatible with closure by suture and what calls for a graft, and, when in doubt, adopt the latter; for most of the failures of wound closure arise when we try to close by suture a wound for which the skin loss indicates grafting.

In certain circumstances we can with success suture with some degree of tension in the presence of minor skin loss; but there are two contra-

indications to suture under tension of any degree. By tension we mean tension over and above that normal to the skin of the area under consideration.

Contraindications to Tension.

1. The first contraindication to suturing under tension arises when any embarrassment to the function of a joint or orifice is produced. For example, it is easy to suture an upper cheek wound, even with a relatively high order of skin loss; but such is not permissible if the slightest drag on the eyelid is produced. So too with the apparent excess of skin on the back of the hand—it is easy to suture a wound with a local high order of skin loss; but this apparent excess of skin is needed for free metacarpo-phalangeal joint function.

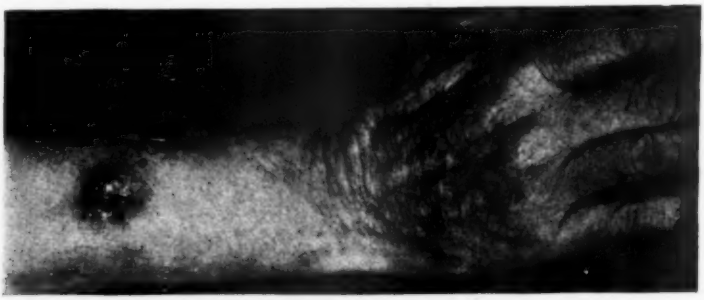

FIGURE IIA. A lesion on the forearm, the nature of which was doubtful, for which biopsy was advised.

FIGURE IIB. Ten days after excision of lesion shown in Figure IIA and application of a thick split skin graft. Again the graft makes adequate excision of the lesion compatible with primary closure.

In such important areas any skin loss is an indication for graft, not for suture (Figures IA, IB, IIA and IIB). On the contrary, the same amount of skin loss on the abdominal wall could be rectified by suture with no untoward functional upset.

2. The second contraindication for suturing under any degree of tension is sepsis, or even the possibility of sepsis in any degree. Thus a degree of tension permissible in the primary closure of a clean surgical wound is not permissible in any secondary suture. As I shall show later, primary closure might be indicated under certain conditions with some traumatic wounds of soft tissue; but again the indication is for graft in all cases with appreciable skin loss, for here there is always a possibility of sepsis. We can have some degree of tension in a clean wound or some degree of low-grade infection in a wound that lacks tension. Neither instance is incompatible with a satisfactory

wound closure; but tension with sepsis in the same wound causes inevitable breakdown with healing by secondary intention, undue scar and a relatively inferior result.

So every surgeon realizing the indications must cease to shirk the skin graft. If our past experience of skin grafting wounds has been an unhappy one, we must check over mistakes and take stock of any recent advances in application or technique.

PRIMARY GRAFTING OF WOUNDS.

From the point of view of the wound itself the indications for primary grafts are essentially the same as those for primary suture. They imply that the wound is already surgically clean, or that it is in such a state that we think we can make it surgically clean. So we must consider from this standpoint of a clean surgical wound: (i) the type and site of the wound; (ii) the circumstances of its production; (iii) its relationship to the injured individual; (iv) the local facilities and circumstances, including the surgeon's capabilities; (v) the time factor.

To these must be added certain local conditions in the wound and facilities available for the grafting process; these will be detailed later when we discuss the types of graft indicated.

1. *The Type and Site of Wound.*—Certain irregular lacerated types of wound involving essential structures may be impossible of ideal surgical *débridement*. This would also apply to the "through-and-through" type of wound. For this reason—and there are many others—most battle casualties are outside the scope of primary graft, as indeed they are for any form of primary closure. On the contrary, clean-cut amputations through the hand or scalp avulsions, for example, as they often result from accidents of industry, are devoid of hidden tracks and pockets, and may well be suited for a primary closure by graft. This measure may save untold hospitalization, to say nothing of the curses of slow secondary intention healing.

2. *Circumstances or Cause of the Wound.*—There is a vast difference between a clean skin loss inflicted by flying glass and a wound associated with indriven débris, infective particles of clothing *et cetera*. One usually is and the other may, or may not, by surgical *débridement* be rendered safe for primary closure. There is a vast difference between the fracture made compound from within and that made compound by the application of violence from without; again one is usually safe for primary closure, while the other only may be. Any missile injury usually implies the indriving of potentially infectious material to a degree beyond any guarantee of surgical *débridement* or wound excision. This again takes most battle casualties outside the reach of safe primary closure.

3. *Relationship to the Individual.*—No part is greater than the whole—a wound is only part of the man. The general condition, the general treatment that is necessary, or associated other injuries may contraindicate an operation of primary grafting for a wound which itself is quite suitable.

4. *Local Condition.*—With the modern arrangements and facilities of civil hospitals in any city there should be nothing lacking for prompt and finite treatment. There are none of the hazards and difficulties of early treatment under war conditions or the inevitable discontinuity of management over a line of evacuation. Circumstances in civil life are highly suited to primary grafting of wounds as indicated; military arrangements are not, even if it was otherwise indicated. However, if some mistakes and misunderstandings have arisen in war surgery by a misapplication of methods correct in civilian practice, do not let us make the same mistakes the other way round

when we come to civilian work, where facilities and conditions do permit of applying more finite methods.

5. *The Time Factor.*—We know that the longer the period elapsing before primary surgery, the more likelihood is there that the wound will become infected and that infection will become established beyond the reach of, or perhaps even the indication for, wound excision. The period in which it is considered that primary closure may be made safe, is an arbitrary one. If we want a figure, that of twelve hours would seem reasonable. Beyond this order of time the wound must be considered no longer a suitable subject for primary grafting. However, any figure is quite arbitrary and must be considered with other factors. In some conditions it might well be extended—certainly on the face, for example, with its high order of resistance and reaction to infection.

Due consideration of these factors will show that many wounds with skin loss are quite unsuited to primary closure by grafting, but we may all be surprised how often it can well be applied in civilian work. If, too, we are not constantly trying to stretch the scope of wound suture to cover a field where the real indication is for graft, we must also see better results from primary suturing.

Summary of Indications for the Grafting of Wounds with Skin Loss.

We can summarize then how the main indications arise for primary skin grafting of wounds with skin loss.

1. The traumatic wounds which, by their nature or by surgical *débridement,* can be rendered clean surgical wounds. These would include: (*a*) Certain wounds from mechanical trauma, mostly industrial or transport accidents (Figures IIIA, IIIB, IIIC and IIID). (*b*) Certain burns suited to primary excision—that is, localized burns of third degree, typically electrical or chemical burns which can be well excised early (Figures IVA, IVB, IVC, IVD, IVE).

2. The surgical wounds with skin loss, made at diverse operations. These operations would include: (*a*) Excisions of skin lesions, mostly neoplasms, innocent or malignant. (*b*) Operations in which skin excisions are necessary in relation to deeper lesions. For example: (i) in fasciectomy for Dupuytren's contracture when there is extensive skin involvement, (ii) in radical operations for carcinoma of the breast with skin involvement, (iii) excision of certain pilonidal cyst lesions. (*c*) Excision of "chronic" unhealed wounds or unstable wounds in which secondary intention healing may have failed by the increasing ischæmia of local fibrosis. (*d*) Adjuncts to various other plastic procedures, as we shall see later, in relation to the donor areas of certain flaps or whole skin grafts.

SECONDARY GRAFTING OF WOUNDS.

Any wound with skin loss when primary closure by graft has been contraindicated must be considered for secondary grafting if its size would indicate: (*a*) that appreciable healing time would be saved, or (*b*) that the likely scar produced by secondary intention healing would cause any embarrassment to the function of the part. Again we see that size is relative to the functional importance of the region—a postage stamp area on the hand is as important as a hand-size area on the trunk.

Secondary closure is the natural corollary to the primary treatment of soft tissue war wounds by *débridement,* excision, drainage and closed plaster immobilization. Unless this primary treatment is so followed up, half its point is missed. We must never by choice allow any wound of size to undergo slow spontaneous secondary intention healing. Never forget that granulation is the precursor of fibrosis, formation and contraction of which are part of the mechanism of secondary intention healing. This means deformity and/or

FIGURE IIIA. Traumatic crush wound of hand.

FIGURE IIIB. Appearance after *débridement*, which was done five hours after the injury. Primary split skin graft is applied to all areas remaining after exposed bone had been covered by local soft tissue flaps.

FIGURE IIIC. Appearance five days later — almost complete take of graft.

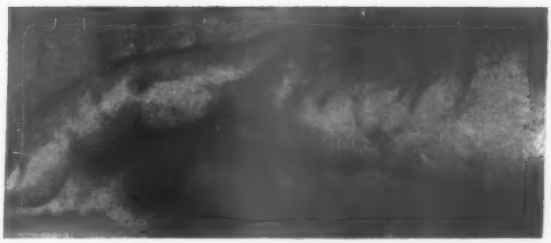

FIGURE IIID. Appearance two months later — main wound healed with negligible scar. Sinus still present from sequestration at site of comminution about interphalangeal joint of middle finger.

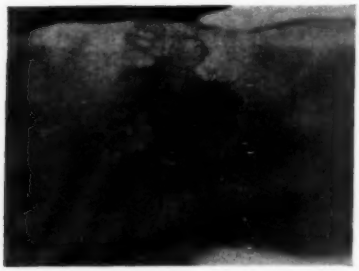

FIGURE IVA.

FIGURE IVB.

Figures IVA and IVB show almost circumferential deep charred burn of wrist and hand by corrosive acid. If this lesion was treated conservatively, it is obvious what time would pass for sloughing and healing, and what morbidity would arise.

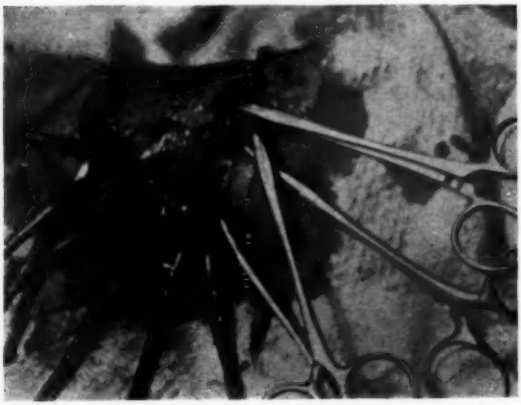

FIGURE IVC. Excision of burnt area within three hours of the accident. Split skin grafts were applied immediately to the wound.

malfunction in some degree. Scar at its best is only a few layers of epithelium, unsoundly attached to a fibrous base. It has none of the stability of true skin to ordinary function or to ordinary petty trauma. The more fibrosis beneath the scar or, in other words, the longer that wound takes to heal, the less stable and more unsatisfactory that scar will be. Skin is an important organ of many functions, but scar is only a makeshift integument.

In practice, wounds for secondary grafting are open granulating areas; but it must not be inferred that granulation is necessary for skin grafting. It may be over certain tissues, but it is a mistake to wait for all wounds to "granulate

FIGURE IVD.

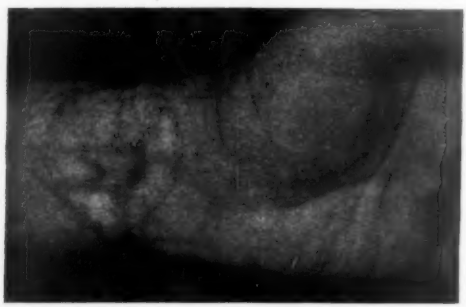

FIGURE IVE.

Figures IVD and IVE show almost complete take of graft. There were œdema and stiffness of the hand, which slowly improved.

up", as we so often hear. From the aspect of skin grafting, a granulating surface means two things:

1. It means fibrosis in the making with progressive local ischæmia.

2. It means an infected surface. Surface infection renders the results of secondary grafts far inferior to those of primary grafts. It has an adverse effect in two ways: (i) Certain types of infection, notably those caused by the hæmolytic streptococcus, have a specific, histolytic or digestive action on vulnerable or new epithelial cells. (ii) Any accumulation of pus can mechanically separate a graft from its bed in the critical phase necessary for its take.

Prerequisites for Secondary Grafting.

The details of preparation of a granulating wound, the type of graft used and the technique of its application are all focused about the element of infection, in recognition of which we can lay down four prerequisites for secondary grafting. These are as follows:

1. The patient must be in the best possible general condition compatible with his wound and the best that supportive treatment, diet, transfusions *et cetera*, can offer. His hæmoglobin value should be over 75% and his blood protein content over 5·8%. With any large open wound these chemical deficiencies in the blood arise by infection and continual loss of surface discharge. They are more prevalent than we realize; they can and should be made right by repeated blood transfusions.

2. The wound surface or the granulating area must be firm, flat and regular—not hypertrophic, nobbly, pale, mushy and painful, which characteristics testify to uncontrolled infection. Hypertonic saline and pressure dressings, as well as specific treatment for surface infection, will render a granulating area mechanically fit for skin. If granulations have been present for months, they can well be removed to expose a firm and more vascular base, which also eliminates some of the potential fibrosis. In still older wounds, fibrotic beyond the possibility of healing, the whole wound, including the dense fibrotic base, should be excised, a surgical wound for primary grafting being thus created.

3. We must know and follow the bacteriology of the wound and by correct specific treatment eliminate the chief offending organisms. These are the hæmolytic streptococci, the hæmolytic staphylococci and *Bacillus pyocyaneus*. Of present available antiseptics, the soluble sulphonamides, hypochlorites, acetic acid and the acridine drugs cover the chief indications of specific treatment.[1]

4. There must be no focus of repeated reinfection of the wound surface—that is, no underlying active bone sepsis, no tendon sloughing, no open joint, and no retained foreign bodies with associated infection.

The infection bugbear with secondary grafting also raises the question of drainage. Just as we might use drainage with a secondary suture, so we can with a graft which need not be looked on as a closed dressing. Holes can be cut in a graft or the graft can be cut up into many skin areas (several people have put their names to this simple manœuvre). Or we can use the well-known, and still most useful, multiple foci of epithelization—pinch grafts.

FREE SKIN GRAFTS AND THEIR APPLICATION.

Having considered in principle the indications for primary and secondary grafting of wounds from the aspect of the wound itself, I shall now analyse

[1] This paper was written before supplies of penicillin were available. We have since shown that penicillin is the best surface agent yet available for eliminating streptococcal and staphylococcal infection from granulating surfaces.

the indications and contraindications to grafting from the requirements of the grafting process and of grafted skin. First I shall deal with free skin grafts and their application. The true conception of skin is that of an organ—roughly one-quarter of epithelial elements, the epidermis and its developments, and three-quarters dermis with its fibrous, elastic, vascular, pigmentary and special nervous elements. We have been taught that the cellular epidermis is constantly in formation from the Malpighian layer. So it is, but it can also regenerate from any of the special developments of this special layer—that is, sweat glands, hair follicles and sebaceous glands. This fact is most important in the understanding of skin grafts, for skin can be split off in varying thicknesses up to, but just short of, its full thickness, and the donor site still be left capable of spontaneous regeneration from the remaining epithelial elements. Any of these split thicknesses, as well as the whole skin, will survive and grow on a tissue surface: (*a*) if it can receive adequate nourishment—as it can from all tissues except bare bone, bare tendon or bare cartilage; (*b*) if also it is kept immobile in direct contact with the surface by pressure for a time, the necessity for both of which increases in degree with the amount of dermis contained in the graft.

If these two basic requirements are satisfied, the graft takes not by chance, but as night follows day. Anything which destroys the life of the graft during this critical phase of take, as can certain types of infection, or anything which mechanically separates it from its bed, as does pus, blood, inadequate or disturbed pressure-fixation, will cause failure—again not perchance, but for a definite reason. We must cease to regard skin grafting as a "hit or miss" business. Failures are due to errors of application or technique.

Types of Free Skin Graft.

The following types of free skin graft may be described (see Figure V).

Epidermal Grafts.—The thinnest shaving off the skin's surface that can be cut with a razor contains only epidermis. This will survive on serous exudate so that it takes easily on a recipient area. But though it takes easily, it has little more than the integumentary function of skin and is an improvement on scar only in the more layers of epithelium is contains. In its new site it invariably wrinkles and contracts. This is because there is nothing inherent in its structure to counteract scar shrinkage in the thin plane of organization between the graft and its bed. Easy take, then, is the main advantage and subsequent shrinkage the main disadvantage of the epidermal graft. This is the true Thiersch graft.

Whole Skin Grafts.—At the other extreme of skin thicknesses are whole skin grafts. The whole skin can be removed by dissection—that is, down to but not including subcutaneous fat. This graft presents no epithelial elements in direct contact with a recipient site. It has a much more precarious existence, and can exist only if early fluid exchange is rapidly supplemented and replaced by vascular ingrowths and connexion with the dermis. The dermis depends on this vascular regeneration for its continued life, on which the life of the epidermis secondarily depends. This take *en masse*, as it were, requires absolutely correct size, shape and tension of the graft relative to the recipient area. Also an accurate, even and high order of pressure-fixation is required. If these essential requirements cannot be satisfied, the whole skin graft will fail just as surely as it will take if they are.

Just as ease of take is the advantage of the thin epidermal graft, difficulty of take is the disadvantage of a whole skin graft. In practice this excludes whole skin for all secondary grafts on potentially infected granulating wounds; nor is it applicable even as a primary graft on some surgical wounds where adequate counter-resistance—which is always necessary for obtaining

adequate pressure—is not available. Thus it is unsuitable in certain highly mobile regions, such as the neck or the axilla, or without special counter-pressure prosthetic mechanisms on a nose tip or near the angle of the mouth. The advantage of whole skin, converse again to the thin epidermal graft, is concerned with its dermal content. Though highly elastic when cut, it undergoes no subsequent contraction in its new site. It seems to possess sufficient strength in its own bulk to counter the small amount of scar

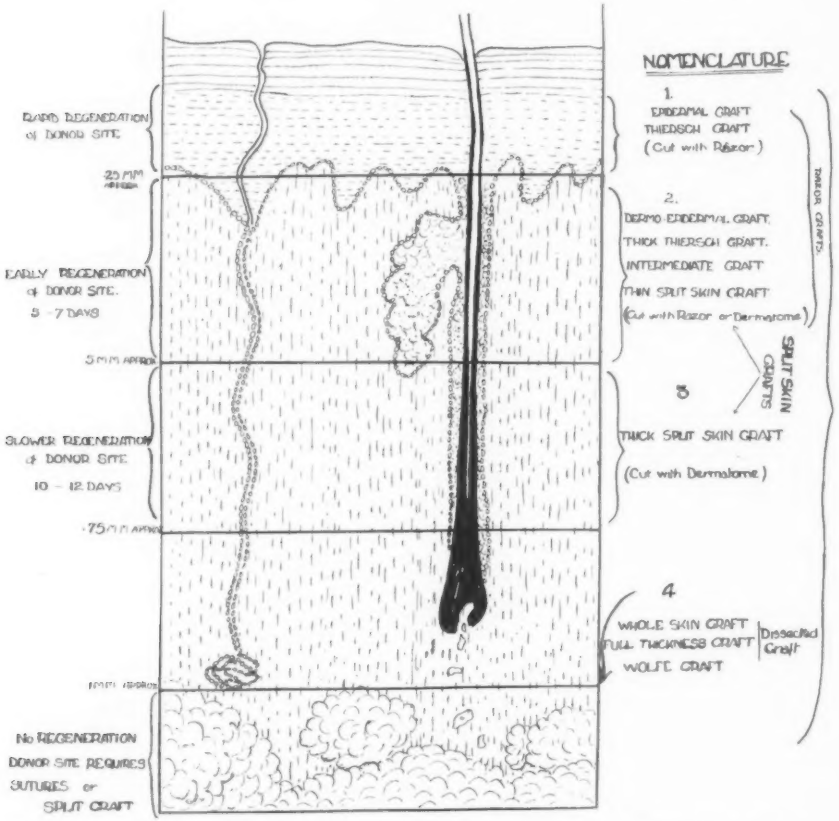

FIGURE V. Diagram of skin section to show the nomenclature and arbitrary levels of four main types of free skin graft. 1: the Thiersch graft; 2: the thin split skin graft; 3: the thick split skin graft; 4: the Wolfe graft. It is to be noted that the regenerative elements of skin are included in hair follicles, sebaceous glands and sweat glands, as well as the Malpighian layer.

organization between graft and bed, which is almost negligible by virtue of the order of pressure-fixation used. A whole skin graft will, in time, regain all the functions of skin, including sensation; in fact, it is normal skin, and were it not for the disadvantages of application and technique, it would be the ideal for skin grafting in all cases of uncomplicated skin loss. Its application is thus restricted to surgical wounds in suitable areas—in practice, the face and hands, following the excision of scars and localized skin lesions.

Split Skin Grafts.—As a compromise between the two extremes of skin thickness, skin can be split in varying degrees. By including more or less of

the dermal element of skin, the advantages of either thin or whole skin grafts are approached. For routine use, though we require the best possible result, we also require an assurance of take without over-elaborate refinements of technique and practice. In most cases this is supplied by the so-called "intermediate" or "split skin" graft about half-skin thickness, split off with a razor knife. In point of fact, this is the graft which many surgeons cut and erroneously call the Thiersch graft. Where there are local technical difficulties in pressure fixation or doubtful grades of infection, the thinner the graft, the better the chance of success, while on more suitable areas and on clean surgical wounds the thicker graft should be used. It is in cutting the thickest of these split skin grafts that the dermatome machine is so useful. By means of it, skin is easily split at an even predetermined thickness just short of whole skin in a manner which is difficult by freehand methods. It can, of course, cut skin of any thickness; but its chief use is to cut a thick split skin compromise for a whole skin graft, for use when we would like to use whole skin were size, requirements and local conditions more favourable.

Thus there are really four arbitrary types of free skin graft: (*a*) the epidermal or Thiersch graft; (*b*) the "dermo-epidermal" graft, "intermediate" or "thin split skin" graft; (*c*) the thick split skin graft; (*d*) the whole skin graft (Wolfe).

Ways in which Free Skin Grafts May be Used.

As Primary Grafts on Surgical Wounds.—Any of these grafts could in theory be used as primary grafts on surgical wounds.

1. The epidermal graft is indicated only as a replacement for mucous membrane, its advantages in this case being that it grows no hair and has no secretion. Because of the disadvantage of its contraction, over-correction is always indicated and it must be always followed by a period of continuous dilatation during its early and more active contractile phase.

2. The thinner split skin graft can be used on any large body or limb raw areas. It is always a graft of choice in less experienced hands. It is always a good palliative where replacement is later indicated by some other type of graft—for example, a flap.

3. The thick split skin graft has the same indications as whole skin (Wolfe graft), but is used on areas too large for a Wolfe graft or where the necessary pressure-fixation is more difficult to obtain—for example, the neck or the axilla. They are very satisfactory as large grafts on the back of the hand.

4. Whole skin grafts (Figures VIA, VIB, VIIA and VIIB) are used principally on the face and hands, where a high order of cosmetic result as well as skin function is required. For the face the area of skin behind the ear, being of correct texture, should be used whenever possible. On the hand the chief indications are for scar replacement and for some Dupuytren's contractures.

In a gross example of this latter condition there is often extensive skin involvement making separation of the palmar skin from the hypertrophied fascia difficult. In raising a large palmar flap for radical fasciectomy one should endeavour to separate it carefully from the attached fascia, for if it is not unduly contracted or damaged at operation, it will survive and function as a whole skin graft if any free fat is removed from it, if it is carefully sutured back and if an adequate pressure dressing is applied. If, however, it is too damaged or involved with the fascia, it should be removed and replaced by a Wolfe graft from elsewhere. We must avoid at all cost any risks of skin sloughing, for it is easy to replace the fascial disability by a scar disability.

When a palmar flap is of doubtful viability its treatment as a whole skin graft or its replacement by a whole skin graft will often eliminate the risk of breakdown and scar formation.

FIGURE VIA. Scar disability of wrist and thumb, result of a shrapnel wound six months previously.

FIGURE VIB. Six months after scar excision and Wolfe graft, now indistinguishable from the surrounding skin, and with complete sensory return, except over a small area in its centre. The outline of the grafted area is dotted; there has been no appreciable contraction of the graft.

As Primary Grafts on Traumatic Wounds.—These grafts may be used as primary grafts on traumatic wounds.

1. The split skin grafts are generally indicated for reasons already set out.

2. The full thickness (Wolfe) graft has one special indication, that rather like the palmar skin flap for Dupuytren's contracture, which has just been mentioned. One is sometimes presented with large avulsed flaps, which may be completely detached, or may be still attached by a narrow base inadequate for blood supply. These loose flaps can be replaced on the wound if primary closure is indicated, but only if they are treated as whole skin grafts. Any fat they contain must be carefully removed, for skin only is the limit of free skin grafting, and a pressure dressing, of course, is required. On the face one often sees meagrely attached flaps of tissue, resulting from a head-through-windscreen accident, for example. We miss a big opportunity if these flaps are not correctly prepared, put back and treated as whole skin grafts.

As Secondary Grafts.—These grafts may be used as secondary grafts.

1. Split skin is indicated for routine use and will produce a most satisfactory result in the majority of cases. Drainage can be provided for, as has been indicated.

2. Pinch grafts, despite some of the criticism they receive on the score of bad cosmetic results, rightly still hold a place in secondary grafting. They are within the technical capability of all, and are always an excellent palliative to bring about early healing. (See Figures XVIIA,

FIGURE VIIA. Old burn scar contracture of little finger of many years' standing.

FIGURE VIIB. Two months after scar excision and Wolfe graft (outline dotted). Residual extension limitation is due to long-standing joint change and is typical with long neglected scar deformity.

XVIIB, XVIIC, XVIIIA, XVIIIB, XIXA, XIXB, XIXC and XIXD.) They can easily be replaced later. In effecting healing of large war wounds and burns in sick men we have found them invaluable and often life-saving. Moreover, they often given permanently satisfactory results (see Figures VIIIA and VIIIB). The thicker areas of the pinches themselves have some stabilizing effect on the scarred areas of secondary intention healing among them. The indications for their use are: (*a*) Small areas for which an anæsthetic would

FIGURE VIIIA. Pinch grafts still have a place in effecting the healing of large raw areas and may give permanently satisfactory results. Figure VIIIA shows a crop of pinch grafts over residual raw areas in a debilitated and extensively burnt patient, with a limited area of available donor skin. Note the pressure sore.

FIGURE VIIIB. The same case two years later. The grafted areas give negligible trouble, and the soldier has continued service in a field workshop.

be unwarranted. (*b*) When an anæsthetic is contraindicated. (*c*) As a palliative for later replacement. (*d*) When there are large raw areas associated with bone sepsis—a large open wound may so be contracted to a sinus.

ATTACHED FLAPS AND THEIR INDICATIONS.

Bone devoid of periosteal covering, bare tendon or fibrous joint capsule or any long-standing avascular area of fibrosis does not offer a surface which can adequately nourish a free graft. These structures in a wound surface contraindicate free grafting at least over the area upon which they present.

In these circumstances primary grafting can be carried out only if the graft includes facilities for its own nourishment—that is, if it is an attached graft or a flap. This may be obtained locally (local flap) or from some suitable distal point (direct flap).

These attached flaps of skin and fat are not generally suited to secondary closure of the wound, and if established bone sepsis or tendon sloughing is present they are generally contraindicated. They are, however, sometimes indicated as secondary grafts on a granulating wound, such as one with exposed tendons on the back of the hand, where some degree of tendon sloughing from a failing blood supply is imminent. Tendon disintegration can sometimes be prevented by a timely flap as an early secondary procedure if other factors for secondary wound closure are adequate. From these contraindications to the use of a flap as a secondary graft two points should be obvious: (i) We must take all suitable opportunities for the primary use of a flap on vulnerable areas of bare bone, tendon or joint (Figures IXA, IXB and IXC). If they are left bare, sepsis is not only more likely to occur, but in turn will contraindicate secondary closure, and just nothing can be done till tendon sloughing or bone sequestration is completed. It is obvious what havoc this plays on healing time and on ultimate results. (ii) Free grafts must often be used for secondary closure of wounds as a palliative to obtain healing and to be later replaced by a flap.

FIGURE IXA. Slicing saw cutting of three fingers; tendon sheath and bone exposed on two fingers.

FIGURE IXB. After attachment of abdominal flap to index and middle fingers. This was done after initial *débridement* within a few hours of injury. A free graft was applied to the ring finger (skin loss only).

FIGURE IXC. Final result. Healed with good soft tissue pads over the sliced area. Adherent scars over such areas are usually painful and unsatisfactory.

LOCAL FLAPS TO COVER AREAS UNSUITED FOR FREE GRAFT.

With the vascular tissues of the face there is no end to the elaborations of design and methods employed in moving local tissue flaps in elective plastic operations. In most of these manœuvres defects are closed by distributing or passing tension to less important areas. This must not be confused with the indications which occur in traumatic surgery for surgeons less experienced in these tissue manœuvres. We must endeavour to lay down some method or rules safe and applicable in most cases. For this purpose I would enumerate the following.

1. The dimensional relationship of the flap must be such that its length is no more than twice its base, that it is broadest at its base and contains no reentrant angles. This two to one relationship has been established by practice and is the basis of safety with all more elaborate plastic procedures.

2. The axis of the flap must be in or toward its direction of arterial blood supply. On the abdominal wall, for example, any direction would fit this requirement, but on a limb a flap should not be based distally. This would make it vulnerable to venous engorgement and asphyxia livida.

3. In the raising of the flap, the total wound area—that is, of the original wound and that caused by raising the flap—should never involve more than half the circumference of the limb or embarrassment to lymphatic drainage will arise. This puts a limit to the size of local flaps—on a leg, for example.

4. The tension of the flap in its new position must be its normal skin tension. Due relaxation can be obtained only if a free graft is applied to the donor site of the flap. One is not using a flap as an alternative to a free graft, for the graft is still essential to make good the skin loss. The local flap is a means of transferring the defect from an area where it cannot, to one where it can, be covered by a free skin graft. Often we see a good flap correctly sutured across a vulnerable area, but instead of its being complemented by a graft, the back edge of the flap is sutured again to the area whence it came. This means tension and something often suffers, certainly if there is any degree of sepsis; either the suture line breaks down or else the vitality of the flap itself is ruined.

These four considerations of design—size and dimensions, direction of blood supply, size relation to the part, and its tension—are by no means rigid. They are all on the side for safety which must be. It is no consolation for a bad result to have been nearly, but not quite, correct in design. All are integrated variants and we can allow latitude in one requirement if the others are more rigidly applied. For example, we can raise a flap on a leg on a distal base, but we should cut down the dimensional relationships more towards an order of one by one.

Loss of the apex of a flap or of the graft itself—the two common types of failure—can be reduced by attention to these points of design and by ensuring at operation hæmostasis in and beneath the flap. Hæmatoma may cause apical death of the flap by causing tension, and it usually spills out under the graft to cause certain graft failure. This applies whenever a free graft is used in juxtaposition to a well undermined edge or a plastic flap. Hæmostasis must not be left entirely to a pressure dressing. Light pressure is helpful to a flap by preventing engorgement; but extreme pressure is bad for flaps and is not required for the routine split skin graft. For these grafts fixation is more important than pressure. Only light pressure is required for surface apposition, and might well be looked on as one of the means of obtaining the absolute immobilization which is necessary.

GENERAL APPLICATIONS OF THE LOCAL FLAP AND FREE GRAFT.

The opportunities for the application of local flap and free graft (Figures XA, XB, XC, XD, XIA, XIB, XIIA, XIIB, XIIIA and XIIIB) are frequent if we are on the lookout for them. They can be summarized under the following three headings.

FIGURE XA. Shows two typical "chronic" wounds the result of gunshot wounds eighteen months previously. In this case treatment had consisted of primary wound excision and closed plaster immobilization. The wound in the right leg is fixed to the peroneal tendons; that on the left leg to the *tendo Achillis*. Both wounds are subject to the strain of deep fixation and movement, and healing is arrested despite their relative bacteriological cleanliness. Even if they do heal, the scars will not be satisfactory, and will cause functional embarrassment by drag on the tendons.

FIGURE XB. Shows the result of excision of the wounds and rearrangement by local flap and free grafts, so that there is no superficial scar overlying the muscle plane of scar, which is never entirely eradicable. The result is good, the scars and grafts are quite stable, and there is no drag or functional embarrassment.

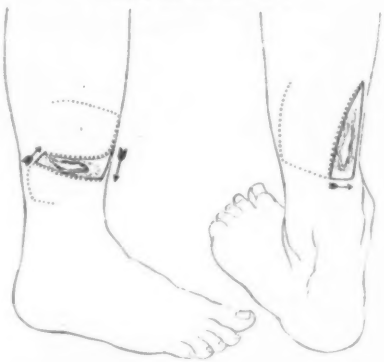

FIGURE XC.

FIGURE XD.

Figures XC and XD are line drawings explaining the principle of the rearrangement. On the right leg two flaps were required, because of the shape and distribution of the wound. It is to be noted that the flap on a distal base has been made shorter, as explained in the text. The dotted line shows the incisions made, the arrows show the direction of flap rotation, and the black areas are grafted.

1. For covering traumatic wound areas where bare bone, bare tendon or bare joint capsule present—in respect to the general indications for primary wound closure.

FIGURE XIA. Healed result of explosive bullet wound of buttock across the sacral region. Healing was effected by a palliative crop of pinch grafts four months previously. Note residual, unstable and adherent scarring over the vulnerable sacral area.

FIGURE XIB. Five weeks after scar excision and rearrangement by local flap from the right lumbar region, and split skin graft to the donor site of the flap. The scarred area to the left of the main flap was subsequently reexcised.

FIGURE XIIA. Residuum of explosive bullet wound of thigh eight months after injury and four months after a palliative crop of pinch grafts. The wound is still unhealed, unstable and fixed to the hamstring muscles, with functional embarrassment. There was an incomplete sciatic nerve lesion.

FIGURE XIIB. Two months after radical secondary excision of the wound and of as much deep scar as possible, with extensive rearrangement by large descending rotation flap on the lateral side of the thigh. A split skin graft was applied to the donor side of the flap. Thus the skin was free of any fixation to deep scar and muscle. The function was good, and it would seem that the sciatic nerve might have a better chance of recovery, devoid of surrounding scar and with healthy vascular tissues about it.

2. For replacing areas of vulnerable scar over bony prominences that are exposed to trauma or require a mobile soft tissue base which a free graft would not supply. Such areas are many—over the sacrum, the iliac prominences, the ankles, inner aspect of first metatarsal head or outer side of

the fifth, over the acromion, and bony prominences of the elbow or the knuckles.

3. For dealing with scars when elective procedures of orthopædic work, tendon repair or peripheral nerve surgery are indicated in association with scar excisions. A free graft is not suited to direct contact with a bare area of bone, as we have seen, nor the suture line of a tendon or nerve. In many of these cases a well designed local flap will permit of these procedures, though some of the more extensive lesions will require correction separately and beforehand. Flaps may need to be migrated from an opposite limb or the abdomen.

FIGURE XIIIA. Shows the condition seven months after a bomb shrapnel wound over the right ilium. There is skin loss and a large amount of deep scar fixation. Two months previously a skin graft had been done with failure, and two subsequent attempts at secondary excision and suture broke down with sepsis and tension.

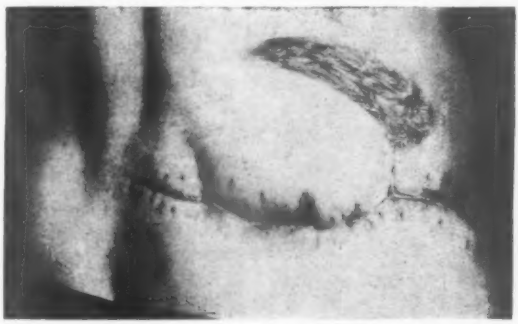

FIGURE XIIIB. Result five weeks after wound excision and closure by local flap and free graft, which was considered the correct secondary procedure for this wound (prepared with proflavine). The tension factor was thus eliminated from the secondary suture line, and the free graft was placed on a healthy base, the prime causes of failure with previous attempts at secondary wound closure being thus eliminated. Typical contraction of the thin split skin graft is obvious. This soldier returned to his unit one month later.

One of the applications of the local flap *plus* a free graft is in certain cases of pilonidal cyst or sinus excision. One is thinking more of the patient with multiple sinuses, who perhaps has had multiple operations. There may be much local scarring with unnatural obliteration of the upper part of the natal cleft, a defect which may cause considerable discomfort. In these more complicated or gross cases more than usual skin excision is required. How is a primary closure to be effected in these cases without undue tension in an area prone to infection? The skin loss must surely be made good and free use of a graft in such conditions might well improve the results on two scores: (i) it might encourage less timid local excisions and less recurrence if the surgeon is not thinking of primary closure in terms of tension suture; (ii) there might be fewer breakdowns of many primary closures if skin removal were correctly interpreted as an indication for replacement by graft.

Undue amounts of buried suture, dead space and hæmatoma all predispose towards infection. They are frequent accompaniments of tension, and the factors which so often precipitate breakdown.

When and How Should the Graft be Used?—Block excision of this region usually leaves bare the sacro-coccygeal fascia. This is a vulnerable area and

unsuited to a local free graft. A graft here will take if due precautions are taken (see Figures XIV, XVA, XVB, and XVI); but its subsequent stability is not always satisfactory, nor is its fixation to deep structure. For these reasons we can well apply the principle of the local flap and free graft, so that the defect can be transferred to an area where an ordinary split skin graft proves adequate and satisfactory (see Figure XVI).

DIRECT FLAPS.

When the extent of the lesion or local conditions are unsuited to a local flap—for example, an extensive skin avulsion on the back of the hand with exposed tendons, the flap must be obtained from a distant area, usually the abdomen and sometimes the upper part of the thigh (Figures IXA, IXB and IXC). There are few indications for such a primary direct abdominal flap, other than surgically created wounds. Occasionally a flap is indicated as a secondary graft on a granulating wound (usually after burns) when exposed tendons are in jeopardy. Here again the same size relationships hold and the indications are exactly the same as with local flaps. Again a free graft is required on the donor site of the flap, for if a large area is left, a calamity by sepsis can easily result. The flap must be designed carefully with respect to position of donor and recipient regions.

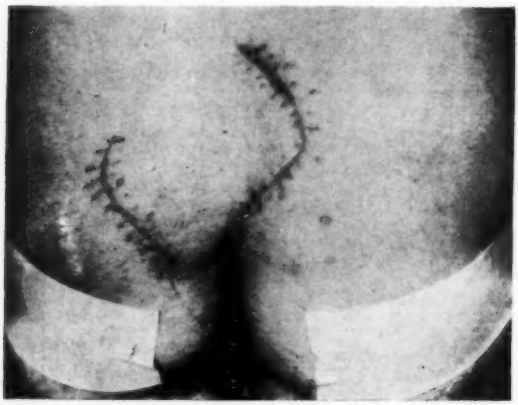

FIGURE XIV. An extensive local flap (Estlander). By rotation advancement of a large flap the defect is covered and the tension distributed over a long suture line, a major portion of the tension being on that part of the suture line remote from the vulnerable area. Note that the base of the flap is not the widest part. This calls for care in design and application of such flaps in poorly vascular areas.

In some cases the area and size requirements of the flap cannot be respected by a single direct flap, and a double attachment is indicated—that is, a "hand-in-pocket" type of flap. This, in principle, can be considered as two flaps joined together in their middle, each with a separate base, and thus the safe dimensions of the whole flap can be worked out. With a relatively longer flap it may be possible to close the donor site on an abdomen by direct tension suture, but a graft is often indicated even on the abdomen and always on other regions.

CONCLUSION.

The correct use of the grafts that we have considered with due regard for the principles involved, will meet the need which any surgeon might meet arising from the primary surgery of injury, or in routine surgical operations. Any of the more elaborate stage migrations are time-consuming procedures of an elective nature and cannot satisfy the requirements of a raw area which presents as an emergency. Their ultimate indication might be obvious at the time, in which case a palliative skin graft is usually indicated (Figures XVIIA, XVIIB, XVIIC, XVIIIA, XVIIIB, XIXA, XIXB, XIXC and XIXD).

The importance of every surgeon being confident and competent with a skin graft should be obvious—so as to abhor raw areas, and prevent many of the problems of scar disability and deformity. It always simplifies the restoration or substitution for parts lost by injury or disease if fibrosis, the stigma of secondary intention healing, is minimal or absent.

FIGURE XVA. Local primary graft after block excision. Photograph taken at first dressing after removal of Stent mould from the virtual cavity. The graft is complete.

FIGURE XVB. The same case six weeks later, showing the contraction which has occurred in the graft, which is now fixed to deep structures in a vulnerable area. This procedure does not prove permanently satisfactory in a number of cases.

Some of the possibilities of more advanced reconstruction I leave to the films you will see tonight and tomorrow. They show a cross-section of the work as being carried out in a special plastic surgery unit for the injuries of war. You can form your own conclusions, but I think you could infer in these directions:

1. That it has some bearing on the indication of primary treatment of certain types of injury and disease: (*a*) That excision of traumatic wounds with skin loss on body areas should be free and not half-hearted. Nothing is gained by leaving an extra half an inch of skin, possibly jagged or undermined and a nidus of infection which would spoil a primary graft or postpone unduly the necessity for a secondary graft. It is just as easy to graft an area six and a half inches by four and a half inches as it is to graft one six inches by four inches. (*b*) Conversely, with injuries of the face and hands, conservatism in primary surgery is to be preferred; the special structures of both are hard to replace, and every extra tag of an eyelid or piece of finger is worth its weight in gold as a basis to subsequent plastic work. A finger can

FIGURE XVI. Shows the use of the local flap and free graft. This is considered the most satisfactory method of making good the skin loss. Tension is eliminated in the vulnerable area, and the graft proves satisfactory on a soft tissue base away from the mid-line.

always be easily amputated later if it really is no good. Its filleted soft tissues may be of inestimable value in dealing with some subsequent scar disability or facilitating the covering of a secondary tendon repair. Fortunately, both these regions have a good blood supply and a high order of reaction to injury

FIGURE XVIIA. One month after gunshot wound of leg, which was followed by radical excision of the calf muscles for a gas-infected wound. Patient had malaria and marked general debility.

FIGURE XVIIB. Wound healed temporarily by palliative pinch grafts applied six weeks after the injury.

FIGURE XVIIC. Final result ten months after injury. The pinch grafted wound with surrounding and deep scar—as far as possible—was excised. The amount of scar tissue was minimum because of early healing effected by the pinch grafts. The defect was filled with skin and fat from the abdomen.

and infection. (*c*) In the surgery of disease, be it a skin lupus, carcinoma of the breast or a pilonidal cyst, the graft can help to ensure that the disease is always freely and adequately excised as there should be no fear of creating a raw area. By the same argument, the possibilities of face reconstruction might well increase the scope of surgery or even radiotherapy for malignant disease of the face and jaws.

FIGURE XVIIIA.

FIGURE XVIIIB.

Figures XVIIIA and XVIIIB indicate good result for such an injury—that is, the best result compatible with the degree of tissue lost. There is no scar disability or embarrassment added to the muscle loss.

FIGURE XIXA.

FIGURE XIXB.

FIGURE XIXC.

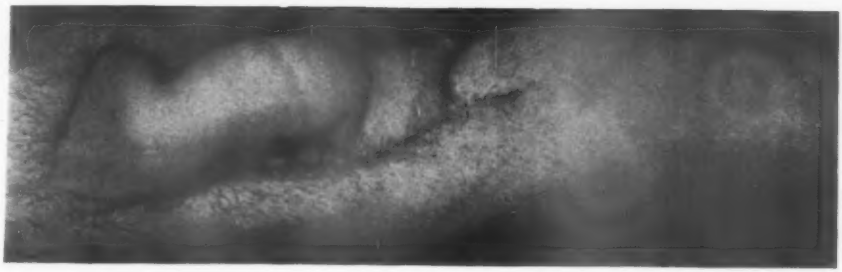

FIGURE XIXD.

Figures XIXA, XIXB, XIXC and XIXD indicate the stages of the flap migration employed. That represented in Figure XIXD is usually omitted, the flap being fully spread on detachment from the wrist. The manœuvre indicated is a means of obtaining extra width—that is, in effect two flaps which can be spread side by side, so as to cater for the irregular shape of the wound.

2. To go also to the other end of surgical management and note just what constitutes the optimum end-result of a disease or injury (Figures XXA, XXB, XXIA, and XXIB), I think you would agree that the possibility of safer, better and more far-reaching eradication of scar has opened the way to an extension of the elective surgery of bone, tendon or peripheral nerves to a degree which might well alter the standard of end-results from many injuries, quite apart from beneficial removal of the pure scar disabilities in themselves. It is in its correct integration with all other branches of surgery that plastic surgery can help most and best attain its own objects—that is, to restore to normal those parts which are left and reconstruct or substitute for the lost.

FIGURE XXA. Shows an extensive adherent unstable scar of the leg with associated peroneal nerve section—at a stage in its replacement by a large abdominal flap.

FIGURE XXB. After replacement of the scar by mobile skin and fat. Peripheral nerve surgery is indicated and now feasible; this can often be done at the last stage of detachment and spreading of the flap.

ACKNOWLEDGEMENT.

I wish to thank the Director-General of Medical Services for permission to publish this paper.

FIGURE XXIA. Malunited, malaligned, compound fracture of leg, one year after injury—note the pinch grafts. Any bone correction was precluded by extensive thin scar fixed to the bone. Shows stage of migration of abdominal flap to replace the scar.

FIGURE XXIB. After corrective osteotomy (Lieutenant-Colonel E. S. J. King) made possible by the soft tissue repair. Œdema of the foot slowly improved.

ABDOMINAL SURGERY IN FORWARD AREAS: OBSERVATIONS MADE IN A CASUALTY CLEARING STATION, 1941-1943.[1]

By LINDSAY S. ROGERS,
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THE place best suited for abdominal surgery is the casualty clearing station. It is stable, it has beds and it now has sisters. Above all, post-operative care can be adequately carried out, both in advance and retreat. The formation of field surgical units has not altered our opinion in this matter.

Never before has such a high recovery rate been achieved in abdominal injuries. Our present success is due largely to (*a*) exteriorization of all colon wounds; (*b*) universal post-operative gastric drainage and lavage with suction; (*c*) sulphadiazine emulsion applied locally, and sulphathiazole given intravenously; (*d*) resuscitation with whole blood before, during and after operation; (*e*) simpler, quicker and better operative technique.

Thus the improvement has taken place in the management before and after operation rather than in the surgical procedures themselves, which have not altered greatly.

The surgeon must have complete charge of the patient at all stages, though he may and usually will depute parts of the work to the transfusion officer, post-operative officer and so on. The team thus formed includes sisters and orderlies, and becomes a highly efficient force with experience. Members of the team should never act as individuals, but only in mutual cooperation under the control of the surgeon. A good team is only too often broken up by army arrangements, and the surgeon has to start again with willing but often untried hands.

The ideal disposition of the medical officers under the surgeon is that the transfusion officer shall be in charge of the pre-operative ward, and a general duty officer shall be assistant to the surgeon and in charge of the post-operative ward.

It has been suggested that separate resuscitation units be formed to work in advance of the casualty clearing station. What could be worse? To delay the transit of a man with an abdominal injury to a casualty clearing station in order to start resuscitation means valuable time lost, more handling of the patient, and frustration of the blood transfusion if blood loss continues. There is also the subtle error whereby the best time for operation slips by, while apparent benefit conferred by the resuscitation leads to greater delay in the patient's arrival at the casualty clearing station.

The main control of resuscitation must be under the operating surgeon, and the chief resuscitation ward is the pre-operative ward of a casualty clearing station.

DIAGNOSIS OF PENETRATING ABDOMINAL INJURIES.

In the great majority of penetrating abdominal injuries little dubiety exists. The look of the man, the commencing dry tongue, the rapid pulse of poor volume, the examination of the wound, the abdominal pain and rigidity and the history of position and direction of the missile make the diagnosis terribly obvious.

[1] Accepted for publication on April 5, 1944.

Useful points in connection with the examination are:

1. Examine carefully the whole chest, back, abdominal wall, perineum, buttocks and upper thighs after removal of shirt and trousers. There may be two wounds of entry.

2. Every buttock wound should be regarded as potentially an abdominal wound until proved otherwise.

3. Every chest wound is potentially an abdominal wound, and similarly a perforating pleural wound may cause upper abdominal rigidity.

4. Probing a wound gives no information at all and should not be done.

5. The point of maximum tenderness is usually the point of perforation.

6. Always examine the urine for quantity and presence of blood, and the rectum for blood, perforation, foreign body and tenderness.

7. Inquire whether breathing causes pain in shoulder and/or pain or discomfort in pelvis or rectum.

8. The size of the wound of entry means nothing in regard to depth of penetration.

9. Penetrating wounds of solid organs usually produce symptoms and signs to a lesser and slower degree than those of hollow organs.

10. In the few cases in which there is doubt as to the advisability of operating, carry out a rapid "Donald's explorotomy": (*a*) if the amount of "shock" seems out of proportion to the external wounds; (*b*) if the hæmoglobin value and red cell count are lower than normal in early cases, or the white cell count is higher than normal in late cases; (*c*) in the event of failure of the patient's condition to improve in a reasonable time.

THE X-RAY PLANT IN THE FIELD.

The X-ray plant is of extreme value in the field, and in every case of penetrating wound of chest, buttock and upper thigh an X-ray examination in one plane is carried out as a routine. Two planes are used only in difficult cases. The X-ray department is placed at the distal end of the pre-operative ward and therefore allows of maximum efficiency with minimum handling.

Rapid information is obtained on the following points: (*a*) the antero-posterior position of the foreign body and whether it is likely to be in the abdominal cavity or not; (*b*) the size and shape of the missile; (*c*) its direction and course in the antero-posterior plane.

THE BEST TIME FOR OPERATION.

Once the diagnosis of penetrating wound of the abdomen is made, the next duty is an assessment of the resuscitation required. This is done by the surgeon and the transfusion officer. The three essentials, in order of importance, are warmth, blood in cases of fluid loss, and freedom from pain and anxiety. With these essentials attained, the blood pressure rises and the pulse rate ceases to rise. The face, nose, hands and feet become warm and the patient says he is better. Operation is safe when the blood pressure has reached a level of 80 millimetres of mercury, diastolic, and 100 millimetres, systolic; but if after two pints have been run in fairly rapidly no improvement takes place, or improvement ceases, then operate at once to stop the internal hæmorrhage. Transfusion alone will not stop a bleeding mesentery—operation will.

PLANNING THE OPERATION.

The abdomen should not be opened without previous consideration of the viscus most likely injured, whether solid or hollow, the direction of the track of the foreign body, and its probable position.

A large incision gives the best access and permits of thorough and speedy surgery. The man's life is at stake, and the scar left is a small matter. A quick split rectus incision in the mid-zone is used for wounds of the small intestine. Kocher's incision is useful for subcostal wounds, and for those above the groin one similar to that used for exposure of the ureter. Transverse incisions are of value in securing better exposure if a mid-line incision has already been used and for wounds with a viscus protruding in the lateral line. When distension is already present one hundred cubic centimetres of 0·5% "Novocain" solution injected under the peritoneum as the abdomen is being opened is a great help, relaxing the peritoneal layer and aiding subsequent suture.

TECHNICAL POINTS.

The time factor of itself does not preclude operation. Patients whose condition is three days old have been saved.

Once an opening has been made into the abdomen, rapidly suck out all free fluid, not forgetting the pelvis. (A good sucker is made by soldering two pipes into a Jerry can. To one attach a rubber tube to a flushing curette. To the other attach a tube from a tire pump with the washers reversed.)

The control of bleeding is the first step if blood is encountered. If it is coming from the deep epigastric or other vessel in the ventral abdominal wall, understitch and tie the vessel. If the hæmorrhage is retroperitoneal, open the hæmatoma and find the bleeding point. If the liver is the source, use deep mattress sutures and an omental patch; if the spleen, splenectomy. In the case of torn edges of bowel or mesentery, understitch the area and tie the sutures.

If formed fæces are found, examine the descending colon and rectum; if fluid fæces, the small intestine. If formed food substances are found, examine the stomach.

In thoraco-abdominal wounds, respiratory stability is of paramount importance. A sucking wound of the chest wall is closed first. If the wound in the chest wall is not sucking, the hole in the diaphragm is closed as soon as the peritoneum is opened.

In exploration start with the large intestine. If a hole is found, use lateral mobilization and exteriorization of the part. Begin next at the ileo-caecal junction and go through small intestine and stomach once, thoroughly and rapidly, clamping each hole with a Poirier's forceps. Inspect finally the bladder.

Points Relating to Repair of the Gut.

One perforation nearly always means two. Repair is always better than resection if it be possible. End-to-end junction after resection is best for small intestine. It facilitates the sewing of a thickened hæmorrhagic mesentery, it leaves the smallest traumatized area, and it leaves no blind ends. In all gut without a mesentery remember to inspect the non-peritoneal area. In all loin wounds inspect the *bursa omentalis* (a hæmatoma gives the clue) and bare areas of colon.

The simpler the suture, the better it is. Life-saving measures only are called for, not extensive permanent repairs. A Miller-Abbot tube should be guided through the pylorus at the end of the operation.

In wounds of rectum, bladder and sigmoid colon use the Trendelenburg position only after sucking out the pelvis. The pelvis should be drained after every perforating wound. Blood collecting there often means a pelvic abscess later.

The pelvic drain should be clamped when the operation is finished. Sulphadiazine emulsion is injected down it, and this is then washed into the abdominal cavity by a further injection of thirty cubic centimetres of sterile saline solution. Unless this is done, the drug forms into a pelvic collection and is absorbed very slowly.

Retroperitoneal Wounds.

Distension starts very early and is progressive with retroperitoneal wounds. Stomach suction is not usually sufficient to deal with the ileus. Semi-erection of the penis is often present and is a bad sign. Vascular changes in the terminal portion of the ileum have been noted. If these changes are present at the "explorotomy", an ileostomy should be done. Bowel washouts should be started early. The prognosis in these wounds is on the whole bad.

POST-OPERATIVE TREATMENT.

In post-operative treatment often lies the key to success. The abdominal operation is merely one portion of the whole duty of the surgeon, who must be in his post-operative ward constantly. He must observe every phase of the subsequent treatment, often doing things himself if he wishes to get the best results. He must secure the complete confidence of every man with an abdominal wound.

All patients with abdominal wounds should be retained in beds at the casualty clearing station until the bowels are working and stitches are out. All the abdominal patients should be kept together in the ward. This facilitates bottle emptying and general nursing, and improves morale of all patients with suction going. Flatus competitions can be encouraged, as, for example, by one efficient officer who cried: "Chaps, the sky is the limit." The men cooperate well.

In all abdominal cases continuous gastric lavage and suction are begun at once, the two acts being equally important. One orderly is detailed to keep bottles clean and full and to do nothing else. This is a full-time job in a ward with ten abdominal patients. Lavage and suction are maintained until intestinal movements are continually heard and flatus and fæces are passed.

Fluid balance charts are essential in all cases in which suction is used. Fluids are given parenterally for the first two or three days, then a continuous rectal drip. A dry tongue calls for more fluids—crepitations mean stop them. Drinks and bicarbonate of soda are given often; they wash out the stomach and restore confidence. Plasma, one pint a day, given empirically, acts as a good tonic.

Morphine, in doses of one-quarter of a grain every four hours and half a grain at night, is given continually for the first two days. Sleep and rest to the bowel are necessary. The bowel is allowed to rest for three days, and enemata are then begun. The abdomen is inspected twice a day, and hot copious bowel washouts using postural treatment are begun the moment distension appears.

Sulphathiazole is given intravenously while suction continues. A second dose of sulphadiazine emulsion injected down the pelvic tube has been found to cause intense pain and dysuria for twenty-four hours, and has therefore been given up.

Danger signs in abdominal cases are these: persistent hiccup starting even during operation; slow persistent distension with a silent abdomen; continual anxiety and high pulse rate; diminution of urinary output.

Continuous Stomach Drainage.

Transfusion tubing with two lateral holes at the distal end is satisfactory for continuous stomach drainage. It is stiff enough, passes easily and never becomes blocked. The nasal route is the best, and if the patient drinks water from a spout cup as soon as the cough reflex begins, the tube passes very easily. The use of cocaine is never necessary.

The patient is allowed to drink whenever he feels like it; this washes the mouth and the stomach, and improves morale. Three times a day the stomach tube is disconnected, and five hundred cubic centimetres of hot sodium bicarbonate solution are injected.

When intestinal movements are heard continually, and flatus is being passed, the stomach tube is clamped and fluids are allowed by mouth. If there is no residue at the end of four hours, the tube may be removed. If vomiting occurs, the tube is reinserted immediately.

Impatience to remove the tube is deprecated. Saline solution must always be supplied as long as the tube is in position.

SUMMARY.

The following points have been made, and their application should help towards the recovery of the patient with an abdominal wound.

In the Field.—Two days before battle give all assault soldiers clean clothes and succinyl sulphathiazole. They should enter battle with an empty belly, an empty bladder and a high blood sugar content.

In the Field Ambulance.—Give morphine in full doses, and waste no time on resuscitation except to apply warmth.

In the Casualty Clearing Station.—Better and more stable team work on the part of all members of the team is needed. Operating must be quicker and more thorough. The Miller-Abbot tube should be used whenever ileus develops. Better cards should be used for record purposes.

PHYSICAL CONSIDERATIONS IN EMPYEMA THORACIS.[1]

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ALTHOUGH it would seem axiomatic that, since there is in ordinary circumstances a pressure less than atmospheric in the chest and that an opening in the chest wall results in the passage of air into the pleural cavity, the removal of material from the chest could best be achieved by the use of suction, this proposition has not received the wide recognition from surgeons that it demands. The writers have been unable to comprehend the reason for the various arguments that have been used against the method of negative pressure drainage and therefore the whole problem has been examined both from the theoretical and practical points of view and a statement concerning these is given here. The results obtained by the method—a series of cases was recorded recently (E.R.T.)—indubitably demonstrate its practical value.

Most of the arguments used against the method of negative pressure drainage are principally of an armchair character, and these will be discussed here. Many thoracic procedures deal with conditions in which infective processes are at a minimum, and the relative ease of management of the mechanical factors involved has possibly withheld some of the attention that should be given to the special considerations which arise from serious infection of the pleura or subpleural tissues with its associated exudate.

The various conditions influencing the removal of intrapleural material and the restoration of intrathoracic conditions to normal are discussed under three headings: the physical factors operative in the normal (not infected) chest; those acting in the abnormal (infected) tissues; and physical factors arising in any apparatus employed.

PHYSICAL FACTORS IN THE NORMAL CHEST.

In Ordinary Circumstances.

The feature which differentiates the physical state of the organs of the chest from all others in the body is that they are at a pressure which is somewhat less than that obtaining elsewhere—the so-called "negative" pressure. This is demonstrable by a number of phenomena: (i) the entry of air into the pleural cavity when an intercostal puncture or opening is made; (ii) the progressive passage of abdominal contents into the chest through tears of the diaphragm, the enlargement of diaphragmatic herniæ and the passage of fluid (in some circumstances) from the peritoneal to pleural cavities; (iii) the frequent passage of infections from the neck into the mediastinum (though this may be prevented by the application of suction to the affected area of the neck); and (iv) the projection of the mediastinum towards one side and the formation of pleural herniæ when there is a discrepancy between the pressures on the two sides of the chest. These phenomena are well known and require no elaboration here.

This "negative" pressure is determined by a number of factors. At birth the thorax suddenly enlarges, never to return to its original proportionate size in relation to the lungs—that is, equal in volume to the collapsed and airless lungs when exposed to the pressure of the atmosphere. The lungs contain a considerable amount of elastic tissue, and when they are removed

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from the body they collapse and assume a smaller size than when in the intact animal. Atmospheric pressure is exerted on the surface of the organs and also down the trachea and bronchi of slightly diminishing amount, but the thoracic wall, being rigid, does not transmit the external pressure to the pleura. The importance of the endotracheal pressure is demonstrated by the more complete collapse which occurs if air is aspirated from the bronchi or, if a large bronchus be occluded, with absorption of air from the corresponding region. It is not proposed to discuss here the phenomenon of collateral respiration. In the intact animal the lungs lie in a relatively fixed thoracic cage and occupy a larger volume than that just described. There is thus an elastic pull in the pulmonary tissues so that the pressure in the pleural space equals that in the bronchi less this elastic pull. There is a definite "pull" of the lung away from the chest wall. The lungs are maintained in their expanded position by the position of the expanded thoracic wall and the practical absence of fluid or air in the pleural space, in the same way that the mercury is maintained in a barometer by atmospheric pressure, and the pleural fluid which acts as a liquid film giving a strong but fluid contact between the lung and the chest wall and requires many pounds to the square inch to break it down. The introduction of a needle into the space allows the measurement of the pressure here, and this will be an index of the degree of "pull" of the lung.

The degree of "pull" which is exerted by the lung tissue on the peripheral portion which lies in contact with the chest wall, will depend on the position of the parietes increasing with increased volume of the thorax and thus during inspiration the pressure in the pleural space will be lower—that is, more "negative" than when the chest wall is in the expiratory position, and the tension in the lung higher.

Certain parts of the chest wall move much more than other areas since the chest wall does not expand evenly in all its axes. The operculum (first and second ribs and manubrium) expands mainly in an antero-posterior diameter, the barrel-shaped or intermediate portion fairly evenly in all its axes, the basal portion enlarges mostly from side to side, and the diaphragm increases the vertical extent on inspiration. Thus the amount of pull in different parts of the lung varies with the phases of inspiration and expiration. The elasticity of the lung, however, is not quite the same in all parts. This may be shown readily by distension of the organ in the lung or heart-lung preparation. It may be demonstrated both by insufflation of the lung under "positive" pressure and by "negative" insufflation in a bell-jar. In one experiment on a cat lung for a distance apart of points of 1·28 centimetres at the apex and 1·47 centimetres at the base at atmospheric pressure under a certain positive pressure inflation the distances were 1·53 and 1·85 centimetres respectively (averages of four readings each), giving an increase in length per centimetre of surface of 0·20 centimetre at the apex and 0·26 centimetre at the base. The ratio of extensibility of apex to base was thus $\frac{0{\cdot}20}{0{\cdot}26} = 0{\cdot}77$. At a higher fixed pressure the ratio was $\frac{0{\cdot}32}{0{\cdot}51} = 0{\cdot}63$. Thus the elasticity of the apex is less than that of the base (in the cat) and the fall in the ratio with increased pressure means that we are more rapidly reaching the limit of distensibility of the apex than we are of the base, and this may further be partly related to the smaller volume of the apex. It may thus be observed that the areas where alterations in the chest wall are minimal correspond to those where the elasticity of the lung is lowest—for example, at the apex of the organ; it happens therefore that the relative movement of portions of lung in relation to portions of chest wall is more nearly the same in all parts of the organ

than would be expected from a consideration of either the lung or chest wall independently. Nevertheless the lung, being elastic, conforms to the thorax so that for a specified chest movement different parts of the lungs have moved different amounts by sideways conformation.

Other lung constituents require mention. The superficial limiting layer of tissue on the lung surface—the visceral pleura—is a very thin and elastic membrane, being composed of a single layer of flattened cells and the property of elasticity is well developed. These features are of importance, not only from the point of view of the passage of fluid from the lung spaces to the pleural cavity, but also because in normal circumstances the membrane moves readily and freely with the subjacent tissue and thus does not appreciably affect the physical state of the lung itself. Of course when it is thickened as the result of concomitant or previous disease, it has an important influence which is discussed later.

The subjacent connective tissue, although greater in amount than in the interstitial lung tissue, is also elastic and pliable so that this also—in normal circumstances—may be regarded as an integral part of the organ.

The pulmonary vessels contain a considerable quantity of blood, which, in the arteries, is at a "positive" pressure. These therefore will play some part in maintaining an expanded position of the organ. In addition the actual bulk of tissue (in the walls *et cetera*) will be consequential particularly in the neighbourhood of the hilum. We need consider, however, only the peripheral portion.

In this region it is well recognized that the amount of blood in the interalveolar vessels is dependent directly on the degree of aeration of the alveoli and *vice versa*. Thus though the presence of blood may, by its bulk and possibly its pressure, diminish the collapsibility of the lung, at the same time the aeration and distension of the alveoli increase the elastic tension of the pulmonary tissue. The vessels and their contents therefore do not have to be considered separately.

The bronchi and larger bronchioles, because of their relatively thick and solid walls, also exert a splinting action on the hilar region of the lungs; but this effect is not significant in the outer important area.

The nerves in the lung and subpleural tissues are important from other points of view, but do not influence directly, as far as is known at present, the degree of tension in the lung tissue.

The theoretical determination of the pressure at any part of the chest is difficult, but at any one instant the intrapleural pressure is measured directly by the introduction of a needle, connected to a manometer, into the pleural space. As the volume of the chest is increased with inspiration, the tension in the lung is increased and so the negative intrapleural pressure is likewise increased. If we denote this negative pressure by P_o (millimetres of mercury), then the absolute value of the pressure in the pleural space is $(N - P_o)$ millimetres of mercury, where N = the atmospheric pressure at that time in that situation. Since P_o varies from 5 to 15 millimetres of mercury, then the intrapleural pressure varies from 745 to 755 millimetres of mercury (roughly) —that is, it is normally quite a high absolute pressure.

Summary.

There is a "negative" intrapleural pressure which is different in different phases of respiration and may be different in different parts of the chest. This is determined by a variably elastic organ in a variably movable but nevertheless relatively rigid elastic bony cage. The elasticity of the organ differs very greatly towards the periphery as compared with the hilum, but since the peripheral portion is the significant part, particularly when changes occur

relatively rapidly, this is considered to the relative exclusion of the hilar region.

The nature and amount of material in the pleural space will have an important bearing on phenomena in this region. In normal circumstances there is only a minute amount of pleural fluid between the visceral and parietal surfaces which may be regarded as being comparable with normal tissue fluid and consists of water, salts and probably a small quantity of protein. Its viscosity therefore is little higher than that of water.

PNEUMOTHORAX FROM PHYSIOLOGICAL POINT OF VIEW.

It is necessary before considering the effect of the introduction of air into the pleura in the chest as it occurs with operation in empyema by the open method and also to some degree with the closed method, to discuss the physiological changes associated with normal tissues in the abnormal circumstance of pneumothorax.

We will first consider the case in closed pneumothorax. When the pleural opening is closed following the introduction of air, there is a fall in the negative intrapleural pressure, but there is no pendular air introduced into the pleura with each respiration. As the thoracic cage enlarges, the volume (V) of this contained air is increased and consequently the pressure which was P falls to P^1 since PV = constant (approximately)—Boyle's law. The pressure in the lung alveoli, which varies slightly around atmospheric and is in equilibrium with the air in the pleura so that P = N − T, where P = absolute pressure in the pleura, N = atmospheric pressure, T = tension in the lung, now pushes the lung outwards since temporarily N − T = P > P^1. With the expansion of the lungs T increases and so, though P^1 rises slightly owing to the outward movement of the lung, it does not return to the value P during inspiration for now T is greater. Thus a reasonable fluctuation of negative intrapleural pressure may occur. Graphic representation of this condition by Graham and Bell (1918) shows well that with closed pneumothorax the passage of air through the glottis is not far short of the normal tidal air provided the pneumothorax is not large. Increased thoracic movement can largely remedy the deficiency.

As the lung collapses the blood flow is slightly diminished and some congestion of the lung occurs. If the collapse is sudden, severe effects may sometimes be produced. The development of an acute pulmonary œdema has occurred. Pleural shock is another occasional development, and we have seen one such case in which, though collapse immediately followed the introduction of air with the canvas bag pneumothorax apparatus, when use was made in this patient of the much more flexible method of slow introduction of air by water displacement, good pulmonary collapse was possible without the production of pleural shock. The physiological basis of pleural shock is not understood, but it would appear that morphine and especially atropine are valuable in precluding its development. Some vagal inhibition is suggested by the effect of the latter drug.

With the passage of time the air in the pleura is completely absorbed by the blood and the alveoli may play a part.

In the case of open pneumothorax the intrapleural negative pressure also falls—that is, it approaches more nearly atmospheric pressure—and the extent of this fall will depend on the size of the opening, the size of the glottis and the configuration of the individual. This changed pressure will be faithfully reflected in the contralateral pleura in the young whose mediastinal tissues are more mobile; with increasing age and its concomitant greater mediastinal rigidity this change in the opposite space will be less in proportion to the ipsilateral change. Air also will pass inside the chest with

each inspiration and relatively less through the glottis in proportion to the relative resistances of the chest opening and of the airways. The tidal air then diminishes, as does the vital capacity. The entering air allows cooling of the pleura. Most important to note with open pneumothorax is that with a relatively small opening there is a marked reduction of the negative intrapleural pressure (Graham and Bell, 1918) and the aid to the venous return by this same negative pressure is equally reduced. With a larger opening the vital capacity may fall to that of the tidal air at which life is precarious, since no more oxygen can be brought to the alveolar air than is necessary for the body at rest. This becomes of particular importance in empyema when in addition the lung tissue may be diminished in quality and quantity for respiratory exchange from concomitant or recent disease and the respiratory index, as given by the volume of air necessary to supply 100 cubic centimetres of oxygen to the blood, is increased. Here the normal tidal air is insufficient for rest. The importance of the vital capacity reduction in open drainage was well shown in the case of a child reported in the series mentioned earlier (Trethewie, 1939) in which after open drainage operation for empyema the child collapsed and became cyanosed soon after return to his bed. He had fallen from his pillows. On sitting the child up, a position which improves the respiratory efficiency 25% (East and Bain, 1936) the child's colour immediately improved and his condition was not so parlous.

PHYSICAL FACTORS IN ABNORMAL CONDITIONS (INFECTION).

The local problems in cases in which there is an accumulation of purulent material in the pleura are two: (*a*) the complete removal of pus from the cavity, (*b*) closure of the cavity.

The Removal of Pus.

From what has been stated it is apparent that removal of pus can be achieved easily and rapidly only when the normal negative pressure in the chest is overcome by mechanical means (suction). It is imperative, however, that an adequate degree of suction should be applied. This will be modified by a number of factors, and thus will be different in different cases and at different stages of the same case.

FIGURE I. Cat lung showing absence of distension of pneumonic area in the base of the lung when subjected to positive pressure inflation.

If the tissues remained in the physiological state during the course of the development of an empyema, and the fluid was homogeneous with the same viscosity as air, then the problem would be only that of overcoming the normal negative pressure. There are, however, significant changes in the various components of the empyema wall. It is necessary, therefore, to consider in detail changes: (i) in the lung, (ii) in the pleura, (iii) in the pleural fluid.

Changes in the Lung.—(*a*) The earliest alteration is that of fluid accumulation partly in the interstitial tissues and partly in the alveoli. This alone will make the lung, or the part affected, much less elastic. This is readily demonstrable at any post-mortem examination where the lungs are so affected,

or if the lung is inflated, failure of expansion of the diseased area is readily observed (Figure I). The loss of elasticity is effective, of course, in two directions—collapse of the lung is minimal when the pleural cavity is opened and, on the other hand, it is much more difficult and indeed may be impossible to expand an altered area appreciably. It is quite clear, therefore, that ordinary suction pressure may have no appreciable effect on such tissue and therefore on the size of a cavity.

(*b*) Blockage of bronchi by secretions (such depending in part at least on the diminution of movement of part of the lung) will result in collapse or non-expansion of the related alveoli. Until the block is removed such an area cannot be aerated by any degree of negative pressure (for the moment omitting the question of collateral respiration), but high pressures will affect the whole lung sufficiently to allow distension of deeper areas to compensate for the loss of air-bearing tissue in the vicinity of the cavity.

(*c*) Another factor is cellular infiltration of the lung tissue, and this becomes increasingly important with time, culminating in a fibrosis which may be permanent. It is important that the degree of suction be adequate at an early stage. The effect of fibrosis is demonstrated in cases where late introduction of suction treatment has resulted, in individuals with a relatively mobile chest wall, in collapse of portion of the wall overlying the cavity down to the lung rather than expansion of the lung up to the chest wall.

Changes in the Pleura (Wall of the Cavity).—The pleural membrane undergoes changes comparable with those described in the lung, and such changes may be much more evident than those occurring in the pulmonary parenchyma. In the early stages there are increased vascularity and œdema of the subpleural connective tissues. Thus the membrane loses the characteristic thinness and pliability. Before long there is a deposition of fibrin on the pleural surface. This layer is augmented more or less rapidly until the thickening may become extreme. The rigidity of this layer, depending partly on intrinsic changes in the layer and the extrinsic fibrinous deposit, thus rapidly increases, completely inhibiting a suitably rapid obliteration of the cavity even if "reasonable" pressures (negative) are employed. Late change due to cellular proliferation and infiltration of the fibrinous mass with the resultant extreme fibrosis produces a similar result, though greater in degree and effect than in the lung.

Changes in the Pleural Fluid.—Changes in the pleural fluid depend partly on alterations in the dissolved constituents, but these are insignificant beside the colloid and particulate matter which is introduced into any inflammatory exudate. Thus while pus is composed mainly of water, salts, fats, colloid and particulate matter, it is the colloidal and particulate material which confer upon it its high viscosity. The colloidal constituents comprise protein derived from blood by exudation and from partial digestion of fibrin and degenerate white cells. The particulate matter is made up of leucocytes and fibrin. The proportion of these constituents varies both with the period of infection and the type of organism responsible. In the case of pneumococcal infection fibrin is prominent in the exudate from an early stage. Therefore the viscosity is high at an early stage in such cases. With streptococcal empyemata the fluid is thinly purulent owing to lack of fibrin, but with the progress of time as the cellular content increases it may become much thickened. Staphylococcal infections produce thick pus readily, while the fibrin content is low.

Viscosity is measured by the resistance which a fluid offers to flow. With a tube of length "l" and radius "a" and a fluid of viscosity ρ, the volume flow per unit time V_t is given by the formula: $V_t = \frac{(P_1 - P_2)}{\rho \cdot l} a^4$, where P_1 and P_2 are the pressures at either end of the tube. Thus the flow is directly affected

by the pressure difference and the fourth power of the diameter and is inversely proportional to the viscosity and the distance. Whereas ρ is constant under varying conditions of pressure for a liquid such as water, with colloids the viscosity is changed in proportion to the absolute pressure of the system. The viscosity of a colloid under varying conditions of pressure is readily measured in the viscosimeter. In the case of a colloid—for example, horse serum—the viscosity rises with increase of pressure. Thus with "negative" subatmospheric pressure the viscosity of the fluid is lowered compared to drainage under atmospheric pressure, and so the flow is maintained more readily. But pus is not only composed of colloid. The presence of particulate matter in the form of small spheres in a solution of viscosity ρ_o confers the viscosity ρ on the system according to the formula $\frac{\rho}{\rho_o} = \frac{1 + 0{\cdot}5\phi}{(1-\phi)^4}$ (Einstein), where ϕ = relative volume of the particulate substance, so that as ϕ is increased ρ is increased greatly. If the particulate matter is in the form of ellipsoids, the relation becomes $\rho = \rho_o\left(1 + \frac{\phi \cdot f^2}{15(\ln 2f - {}^3/_2)}\right)$

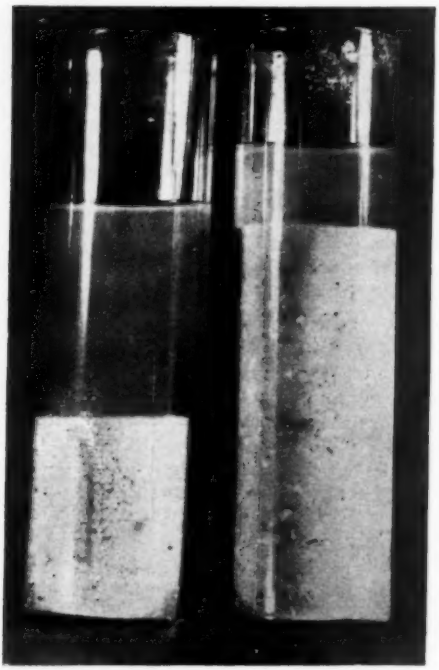

FIGURE II. Specimen of pus removed from chest under closed drainage showing the proportion of particulate matter after sedimentation.

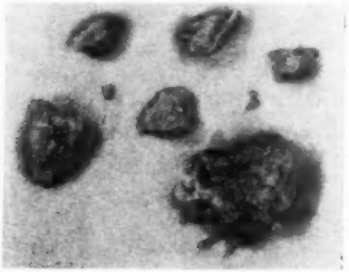

FIGURE III. Photograph of pus particles obtained from the specimen of Figure II —natural size.

(Eisenschitz), where f = axis relation of the ellipsoids. If the particulate matter were to equal half the fluid in amount (as occurs in blood), the viscosity of the liquid would be increased twenty times (for spheres). In Figure II is shown the amount of solid matter in a specimen of pus removed from a chest by suction and then allowed to sediment. The fibrin would give an increase at least equal to that for spheres and the correction for the leucocytes might possibly follow that for ellipsoids. We can then make an approximation for the viscosity of a biphasic substance such as pus, and it becomes apparent that the viscosity is far greater than that of the colloidal constituents which in themselves are very viscid. We can thus replace our first formula by the equation $V_t = \frac{(P_1 - P_2)}{\rho_c l} a^4$, where ρ_c is the approximation for the viscosity which now applies to pus. To enable such a fluid to flow through a tube at a rate sufficiently rapid to counteract sedimentation and blocking, high

pressures such as 20 centimetres of mercury or more are required, and it can be shown that much thick particulate matter can then be made to move—for example, the pus particles shown in Figure III were obtained from an empyema cavity at a suction of 27·5 centimetres of mercury and through tubing 125 centimetres long with an internal diameter of 0·6 centimetre. Furthermore, with increased rate of flow the resistance to flow increases. Again with a moving fluid system the pressure difference ($P_1 - P_2$) increases and is zero when the fluid is stationary. Thus with the application of suction to one end of a tube one metre long the negative pressure at the chest end is much lower if the fluid is moving. The actual figure is given by $P_1 - P_2 = \frac{V_t \rho_c l}{a^4}$. It can also be seen that the difference increases with length of the tube and especially with the smallness of the diameter. It is therefore evident that considerable suction is required to remove pus from a chest through long tubing.

Closure of the Cavity.

Closure of the cavity is rendered difficult owing to three factors which, however, can be overcome easily when due consideration is given to them. Firstly, it is necessary to appreciate the fact that for adequate removal of fluid by suction it is desirable that suction be applied equally in all directions. This would be possible easily only if elasticity of the walls were the same in all parts, and is readily observed in the balloon model first described by

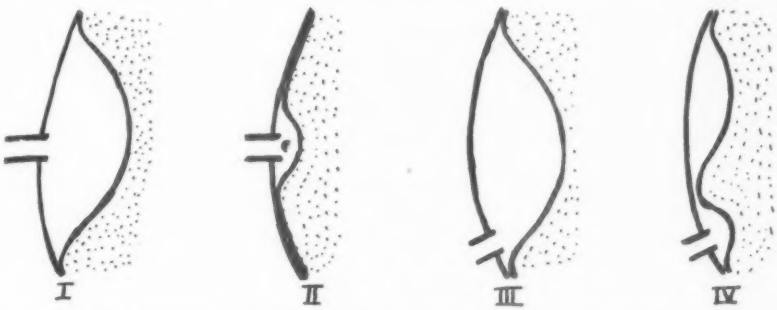

FIGURE IV. Concentric reexpansion of the lung occurring with negative pressure closed drainage. I, II: central insertion of tube. III, IV: excentric insertion of tube.

Revilliod (1872). In such a condition complete removal of fluid is attained by central insertion of the tube since the tube opening is the last place to close [Figure IV (I, II)]. Too low or too high an insertion of the tube will cause loculation, as is demonstrated in Figure IV (III, IV). It is also inimical to drainage to place the tube into the depths of the pleural cavity unless pneumothorax is also present, which will allow the fluid to gravitate to the lowermost portion.

Secondly, the conformation of the thoracic wall, the diaphragm and lungs modify the apposition of the expanding lungs. For example, the diaphragm may cover over a tube placed in the costo-phrenic angle as the cavity is emptied. With a paravertebral collection it is necessary owing to the configuration of the costal recesses and fixity of the vertebræ to place the tube a little to the medial side of the centre of the collection. In addition the lung tissue does not possess the same elasticity throughout—for example, it is found that the isolated lung expands to a greater degree in the basal portion than in the apical portion for the same increase in positive intrabronchial

pressure and the consistency of the diseased lung is varied also from the morbid changes. The relative expansions of the various parts of the lungs in empyema are therefore modified. These difficulties can be overcome by the critical choice of the site of the tube.

Finally, the thickening of the tissue acts as a protection of other parts in alterations of negative pressure either positive or negative. This difficulty is overcome with closed drainage by greater suction, but open drainage depends on this and therefore such interference must be late. It is for this reason that at first, when the drainage tube is introduced into the empyema cavity as soon as the diagnosis is established and the pus is thin, a low suction pressure is applied and the thin fluid will flow at these low pressures. In addition the empyema walls are more pliable at this early stage, so that closure of the cavity is also more readily obtained. With the passage of time and the certain thickening of the empyema walls, higher suction can be applied without the general intrapleural pressure being affected. This was shown clearly in the case of a patient in which suction was applied to the cavity of from 0 up to 12·5 centimetres of mercury on the second day following operation while the negative intrapleural pressure on the opposite (healthy) side with quiet breathing remained unchanged from −3 to −7 centimetres of water, and when on the eighth day the suction was varied from 0 up to 22·5 centimetres of mercury the negative pressure in the opposite pleural space only increased from −2 to −8 centimetres up to −3 to −9 centimetres of water. In addition the greater suction is required at the later stage for the pus is now thicker with increased viscosity.

PHYSICAL FACTORS IN THE APPARATUS.

Conditions ideal for the removal of fluid from the chest are the presence of an airtight connexion in the chest, fluid of minimal viscosity and a tube of maximal diameter. The opening in the chest is placed as near the centre of the parietal portion of the cavity as possible. This position is modified, as explained, in certain circumstances. With a massive collection a portion of the sixth rib in the mid-axillary line is chosen on the right and a little posteriorly on the left. For a posterior basal collection a point midway between the posterior axillary line and the vertebral spines is chosen, and with a collection which does not extend so far laterally (paravertebral in position) the site is at the junction of the inner third and outer two-thirds of the lateral extent of the collection. A drainage tube is not placed low in the costo-phrenic angle because the diaphragm on ascent will occlude the opening. If air is present as well in the chest, the patient will require posturing after much of the fluid has been removed, since the opening may now be above the fluid level, and this is well tolerated with closed negative pressure drainage.

An intercostal puncture hole through which is introduced a tube surrounded by a pressure flange, affords the most accurate fit with little likelihood of leakage. However, sometimes, in cases in which very narrow rib spacing is present, it is necessary to remove portion of a rib to enable a tube sufficiently large in diameter to be introduced. Rib resection is advisable in children and it is necessary to remember that the rib rapidly regenerates. There is an obvious limit to the diameter of the tubing that can be employed. In general, having regard to experience gained with the treatment of patients, it can be said that an internal diameter of about 0·6 centimetre, such as is the case with stethoscope tubing, is necessary. In some cases it will be found that stethoscope tubing, if old, will collapse under higher suction and therefore it is often convenient to employ pressure tubing. In general the narrower the tubing used, the greater will be the required suction.

Owing to the viscosity of the fluid and its biphasic nature a different amount of suction will be required at different times. With the increase in

viscosity with time, so the necessary suction is increased and will usually be 2·5 centimetres of mercury on the first day and daily increases of 2·5 centimetres of mercury are made until the suction applied equals 20 to 25 centimetres of mercury or more. With thinner fluid (for example, streptococcal) the rise is more gradual and the final suction required may be less, whereas with thick pneumococcal pus a more rapid increase may be advisable and the final pressure used may be over 30 centimetres of mercury. The length of tubing will usually be 100 to 150 centimetres, sometimes more, and it is to be remembered that with a flowing fluid the pressure falls gradually throughout its length so that quite high pressures as have been mentioned above are required at the apparatus. Further, the smallness of the internal diameter (0·6 centimetre) of the tube similarly makes such high suctions necessary. The pressure measured is the pressure in the apparatus and not in the chest, so that – 20 centimetres of mercury may not be excessive, and the findings previously shown indicate that no untoward disturbance of pressure in the opposite pleura occurs when the suction is raised gradually so that the condition is proved both from the theoretical and practical points of view. Further, the use of high suction in practice has not, in the hands of the authors, ever occasioned alarm. The thickness of the empyema wall in the later stages, when the suction is highest, guards against such an eventuality as surely as does its presence make drainage of late cases more difficult.

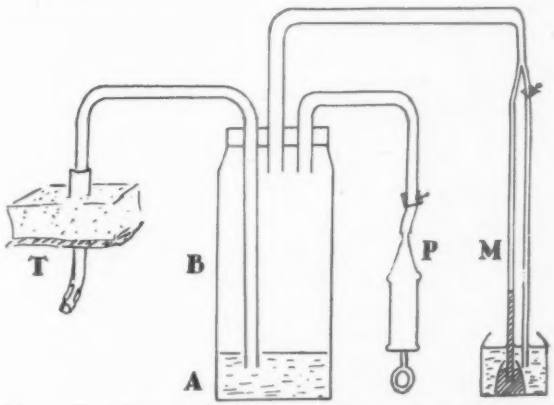

FIGURE V. Diagram of apparatus employed. Details in text.

The results of excessive negative pressure, which can occur in the early stages if the scheme of increased suction previously outlined is not followed, are pain or the appearance of blood in the pleural fluid. The suction must then be reduced. At a later stage the result of excessive negative pressure may be to cause the chest wall to collapse against the thickened non-expansile lung in neglected cases as has already been described (Trethewie, 1939). This, of course, is of benefit to the patient, being a very minor interference for the production of thoracoplasty. One other difficulty is where there is a condition of lung perforation, when it is necessary to allow drainage by siphonage only till the lung deficiency has healed, and thereafter a more gradual increase in suction must be followed.

The apparatus (Figure V) comprises a chest tube (T) passing to a large receiving bottle (B) via a central glass tube which dips down under a mild antiseptic (A) in the bottom of the bottle. The pressure is measured in the air above this antiseptic by a water-mercury manometer (M) connected through the cork. The third opening in the cork, also connecting to the air above the antiseptic, allows the application of a Potain aspirating pump (P) which can be used by hand and is quite adequate, though some prefer an electrically driven motor pump. It is frequently convenient to include an airtight metal drum connected with the bottle B, as advised by Hutson (1938),

for then the suction is maintained for a longer period of time without further pumping.

Provided no makeshift tubing and corks are used there should be no leakage. If the tubing becomes blocked, increased suction may relieve the condition. Sometimes it is necessary to wash out the tubing between the chest and the apparatus, and it may be necessary to change the chest tube in some cases where the blockage is in the chest.

DISCUSSION.

The conditions influencing the removal of intrapleural material and the restoration of intrathoracic conditions to normal have been discussed under the three headings—physical factors operative in the normal chest, those acting in infected tissues, and physical factors arising in any apparatus employed.

It has been shown that a negative pressure is necessary to achieve best the removal of material from the chest. More particularly it has been demonstrated that for adequate removal of pus through long tubing quite a considerable degree of suction is required in view of its viscosity, and this negative pressure in the apparatus must be maintained, and increased as the lung stiffens, as the pleura thickens and as the fluid becomes more viscous.

This negative pressure is quite safe, as has been shown experimentally by measuring the pressure in the opposite pleural space throughout the management of a case of empyema treated by high suction, and more especially has it been demonstrated by the success which has attended its adoption. It must be stressed that at the beginning the suction is not great, but is gradually increased.

The poor results obtained by the early operation, and to which Gerhardt (1890) and Graham and Bell (1918) drew attention, apply solely to the open method. Closed drainage makes early interference safe and should be instituted immediately the diagnosis is made. We have performed the closed operation on patients who were considered too ill for the open procedure with perfectly satisfactory results (Hayward and Trethewie, 1937; Trethewie, 1941).

Apart from the adequate removal of pus and better closure of the cavity afforded by suction, the increased negative pressure will diminish toxæmia by lowering the rate of absorption of toxins and will diminish continued infection of the wall that leads to a fibrosis, which is important in the ætiology of chronic empyema. It will also, by restoring the negative intrapleural pressure, improve the respiratory efficiency, eliminate the dangers of open pneumothorax already alluded to, and aid the venous return to the heart and thereby improve the circulation, and by avoiding cooling of the chest contents aid the heart's action.

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Case Reports.

SUCCESSFUL SUTURE OF FACIAL NERVE TRUNK.[1]

By KENNETH W. STARR,
Lieutenant-Colonel, Australian Army Medical Corps.

(From the Surgical Division of the 113th Australian General Hospital.)

APART from Sterling Bunnell's famous review on facial nerve lesions and their surgical repair, the available literature does not provide much information. The librarian of the Royal Australasian College of Surgeons reports that no cases have yet been published in Australian journals. It is considered, therefore, that this case may be of some interest, more particularly in view of the unsatisfactory comparison between the normal emotional expression and that resulting from neuro-anastomosis and plastic procedures.

FIGURE IA.

FIGURE IB.

Pre-operative right facial paralysis due to gunshot wound—face in repose and smiling.

Clinical Notes.

The patient was Warrant Officer C.W.C., of the Australian Imperial Force (Permanent Force). On August 29, 1942, he was sitting in his tent with his forehead resting on his left hand. His tent-mate was cleaning his revolver and accidentally shot him through the hand, the bullet entering the right corner of the mouth and remaining buried. He was treated at the local field ambulance and sent next day to hospital suffering from a complete right facial paralysis.

On October 2, 1942, one unsuccessful attempt was made to remove the bullet, the operation being abandoned owing to excessive hæmorrhage. Physiotherapy was subsequently employed after the wound had healed and a facial splint was inserted.

On November 4, 1942, the patient was admitted to the Surgical Division of 113th Australian General Hospital. There was a complete infranuclear right facial paralysis without loss of sensation, taste or salivation. Healed wounds were present on the ulnar

[1] Accepted for publication on March 6, 1944.

side of the left hand and at the right corner of the mouth. On electrical investigation the reaction of degeneration was well established in the distribution of the right facial nerve.

On November 12, 1942, operation for removal of the bullet from the right posterior neck was successfully performed by my colleague, Squadron-Leader Basil Riley, Royal Australian Air Force.

On November 20, 1942, I first saw and examined this patient and considered that the right facial nerve had probably been divided. In view of the path of the bullet which was some three centimetres below the course of the facial nerve trunk, the mechanism of its division was not clear.

The great majority of nerve injuries due to missiles which have come under our observation, have recovered spontaneously—that is, they were lesions of the "concussion" type (neurapraxia). Mostly these recover (or show advanced signs of recovery) within four months in our cases. It was therefore considered justifiable to wait till the fourth month before recommending exploration.

On December 4, 1942, there were no signs of recovery, electrical or clinical. Operation was therefore advised. On December 5, 1942, an attempt was therefore made under ether anæsthesia maintained by the endotracheal method to define and trace the cervical branch of the facial nerve to the facial trunk. The congestion and cyanosis of the face deterred me from even making the incision, and the operation was postponed.

On December 9, 1942, under local anæsthesia (1% procaine hydrochloride), the operation was undertaken for the second time, through an inframandibular incision beginning two centimetres above and behind the mastoid tip, passing one centimetre below the mandibular angle to a point two centimetres under the chin. The cervical branch of the facial nerve was first exposed and, above this, the marginal and buccal branches. Their union with the main trunk was exposed, and a piece of stainless steel wire (number 25 gauge) was passed round the trunk in the parotid gland and brought out through the wound, which was then closed.

On December 14, 1942, under ether anæsthesia (endotracheal method), suture of the facial nerve was performed.

The former incision was opened and the wire rendered the exposure of the distal branches of the facial nerve easy. The lower pole of the parotid gland was mobilized by ligating the external carotid artery and facial vein above the posterior belly of the digastric muscle where they perforate the medial border of the gland. The gland was then drawn upwards and the proximal fragment of the nerve sought in the medial lamella of the parotid fascia. Several small fragments of metal (totalling five in all) were discovered in the posterior digastric belly and the parotid fascia. One of these lay in a mass of fibrous tissue on the jugular bulb. On careful dissection, this fibrous mass was defined as the neuroma of the proximal end turned back behind the styloid process (below the vaginal part of the tympanic plate) against the parotid fascia and adherent to the jugular bulb. The stylomastoid foramen and tympanic plate were removed to expose and mobilize the nerve trunk. This actually proved difficult as thickened strands in the injured fascia closely resembled the nerve trunk. Only by the closest attention to anatomical relations, very careful dissection, and scrutiny of the small trunk for its fibrillar arrangement was this stage effected.

The distal branches were traced up to the trunk, which was found on the anteromedial face of the parotid gland with its glioma adherent to the capsule. It had been turned upwards and forwards.

The nerve ends were trimmed with a razor blade to expose the tiny bundles, and traction sutures were placed in the parotid gland to enable it to be drawn back as a relaxation measure while the nerve ends were being sutured. The nerve ends were most carefully examined again. One nerve bundle at the superior part of the proximal and distal segments appeared slightly larger than the others. The nerve appeared to tie without torsion when these nerve bundles were approximated. Accordingly the proximal and distal ends were brought together with two tension sutures of number 40 stainless steel wire suture on the smallest Lane's palate needle, a mosquito forceps being used as a needle holder.

Despite the trunk loss of seven millimetres, this was successful. The nerve sheath was then approximated with human hair sutures (three in all). The parotid gland was brought back to the mastoid process with silk sutures, the suture line being thus relaxed, and the wound was closed with a small rubber drain lying superficial to the parotid gland.

The operation was rendered difficult by the persistent hæmorrhage from the parotid fascia and parotid gland, which had been so extensively traumatized by the injury. The glove drain was removed in eighteen hours.

On December 19, 1942, the patient stated he could feel electric shocks shooting to the corner of his mouth, and a "sensation of his face moving", although he knew it was stationary.

On February 4, 1943, there were no clinical or electrical signs of recovery. As the patient was a permanent soldier from another State, he was sent to Victoria Lines of Communication by direction. But on March 19, 1943, by the kind offices of my colleague, Lieutenant-Colonel E. S. J. King, of 115th Australian General Hospital, the patient was

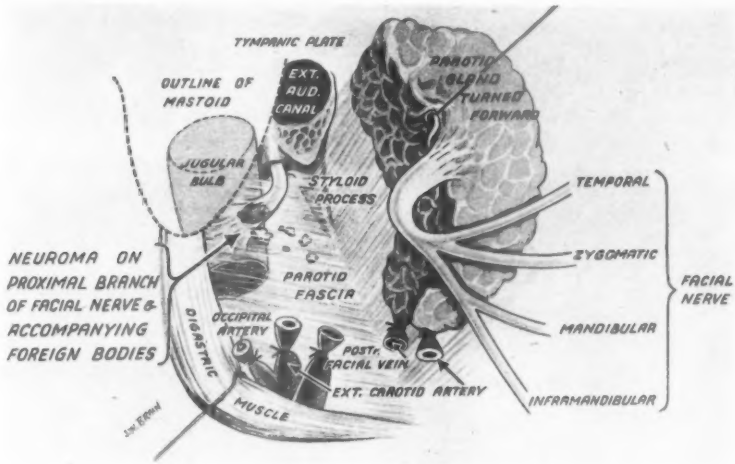

FIGURE IIA. Diagrammatic representation of operative findings.

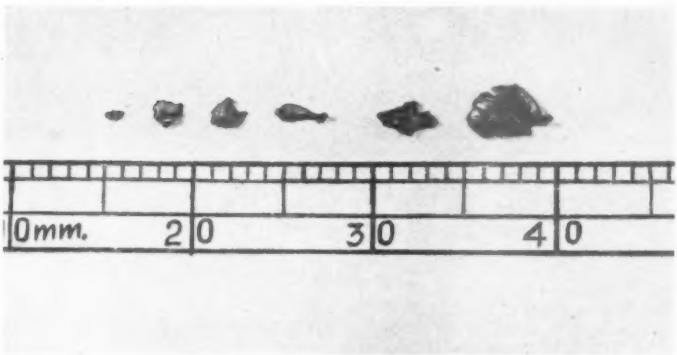

FIGURE IIB. Photograph of portions of metal removed at operation.

returned to me for supervision. Upon his return, examination showed that there was no voluntary movement, but brisk responses to galvanism at milliamperages of 8 to 12 were obtained in all muscles except the *dilator naris*, *frontales* and *corrugator supercilii*.

On March 3, 1943, brisk responses at milliamperages of 3 to 5 were noted in the reacting muscles.

On April 17, 1943, galvanic responses were obtained in the muscles not reacting on March 19, 1943, and the right eyebrow and nostril responded. In the other muscles stronger responses than on the normal side were obtained at 3 to 4 milliamperes. There was definite voluntary movement in the right zygomaticus.

On May 15, 1943, the right platysma showed voluntary movement; strong movement was present in the right side of the face and the smile began to return with more active closure of the eye.

On June 30, 1943, involuntary blink had returned and the natural creases appeared in the naso-labial groove and eyelid.

On August 30, 1943, the power of the *corrugator supercilii* returned voluntarily, but there was no active frontalis movement, which now showed very brisk galvanic responses at 3 to 5 milliamperes. The face was normal in repose, but the paresis was evident on smiling, although the elements of a normal emotional response were improving rapidly.

In July-August an old spear wound of the right leg on the anterior tibial border was first excised and a cross leg flap from the left calf was applied successfully to cover the defect of eight square inches thus created.

On October 14, 1943, faradism was present in all facial muscles, but no voluntary movement was as yet present in the frontalis.

On January 20, 1944, voluntary movement had returned to the forehead.

FIGURE IIIA.

FIGURE IIIB.

Post-operative result at ten months—note returning normal wrinkles and grooves at repose and in emotion.

Comment.

The technical difficulty of performing the operation is compensated by the satisfactory results which apparently follow careful suture of homogeneous nerves (facial, radial and to lesser degree digital).

It is our opinion that at four months after a peripheral nerve injury it is possible to define whether the lesion is of a concussion or interrupted type. The latter lesions show the clinical and electrical reactions of partially or completely interrupted lesions at this juncture, whereas concussion lesions usually manifest considerable recovery. It is our practice to explore all complete lesions of peripheral nerves and to entertain the project in incomplete lesions not showing some signs of recovery at this stage.

It is our further conviction that the result of the operation for nerve suture depends on: (*a*) suture without tension, (*b*) suture without rotation of the corresponding nerve ends, (*c*) suture with the finest non-absorbable material compatible with the tension of the tissue to be approximated.

The employment of sulphanilamide powder (or, more recently, sulphanilamide-"Monacrin" powder) to combat any possible septic infection has in our opinion rendered the operation safe. The combination of skin plastic to eradicate the adherent scar and simultaneous secondary nerve suture is commonly performed in our hands for gunshot wound lesions of the limbs with peripheral nerve interruption.

Acknowledgements.

My thanks are due to the Director-General of Medical Services for permission to publish this case report. The patient was cared for by the staff of Number 1 Plastic Centre attached to 113th Australian General Hospital, and to their unremitting skill great credit is due. Sergeant J. Brain prepared the drawing and photographs, and the typing has been done by Privates Hanson and Todd, Australian Army Medical Women's Service. For her most courteous and willing cooperation, the Librarian of the Royal Australasian College of Surgeons deserves my especial recognition.

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SURGICAL CLOSURE OF A PATENT DUCTUS ARTERIOSUS.[1]

By DOUGLAS G. McKAY,
Adelaide.

M.C., AGED three years and three months, was examined on September 20, 1943, with a view to surgical closure of a patent *ductus arteriosus*. The following is an account of the child's early history.

When the mother was three weeks pregnant she had a mild attack of German measles. A well marked rash was present and one day was spent in bed, but no medical advice was sought. The pregnancy thereafter was uneventful, and the child was born prematurely during the seventh month after a normal labour and weighed three pounds twelve ounces.

There has been some retardation in the child's general development, for it was twenty-three months before she walked and she did not talk until she was twenty-seven months old. Now, at three years and three months, she is very active and alert, talks well, is thirty-five inches high, but weighs only twenty-one and a quarter pounds. Examination reveals a thin, undersized child, with a head circumference of eighteen and a quarter inches. There is a congenital cataract associated with convergent strabismus of the left eye.

FIGURE I. Showing X-ray appearances before operation.

The following is a report of a heart examination made by Dr. E. Flaum on March 24, 1943: "A loud and rough murmur is audible and a thrill is palpable over the whole cardiac region, with maximum intensity in the pulmonary area. The murmur is chiefly, although not exclusively, systolic, and is transmitted to the left axilla and interscapular region; there is no transmission into the large arteries. The systolic blood pressure is 75 and the diastolic pressure is 20 millimetres of mercury. The pulse rate is 120."

The following is a report on X-ray films and screening by Dr. B. C. Smeaton: "The heart is enlarged with filling in of the waist. This suggests left ventricular enlargement with increase in size of the pulmonary cone. The impulses in pulmonary vessels and aorta are rapid and marked with no appreciable reduction in size of the aorta. There is definite vascular congestion in the lung fields." (See Figure I.)

It will be noted that this case fulfils the requirements as laid down by Robert E. Gross[(1)] in his article entitled "Surgical Management of the Patent Ductus Arteriosus". The following is his statement:

"The positive criteria for selection of cases for operation may then be enumerated as follows:

"(1) There must be reasonable assurance that the ductus is patent as is determined by a loud, continuous "machinery" murmur in the pulmonic area,

[1] Accepted for publication on December 22, 1943.

accompanied by an increased second pulmonic sound and a systolic or continuous thrill which is most intense in the pulmonic region.

"(2) There should be evidence of congestion in the lung fields by roentgenologic examination.

"(3) There should be a prominence of the pulmonary artery roentgenologically—though some cases have been reported in which this has been absent.

"(4) There should be roentgenologic evidence of cardiac enlargement, particularly in the region of the left ventricle.

"(5) There should be a peripheral blood pressure which has an essentially normal systolic level, but a definitely lowered diastolic level.

"In short, one should have an indication that the ductus is enlarging, that the individual is not developing properly, that the danger of bacterial endarteritis is high, or that the heart is carrying an increased burden."

The Operation.

Operation was performed on September 23, 1943. The child was anæsthetized by Dr. Gilbert Brown, and the following description of this aspect of the child's management with an accompanying chart is provided by him:

"*Anæsthetic.*—Cyclopropane and oxygen was administered on the mask and then a change made to open ether in order to allow a little more time for intubation. A Magill's tube was passed through the nose, the pharynx packed with 'Vaseline' gauze and then the anæsthetic was continued with cyclopropane and oxygen. Just before the chest was closed the pressure was increased to inflate the collapsed lung.

"*Blood Pressure Chart.*—The child's arm was so small that the ordinary band was too large and had to be doubled.

"When the anæsthetic was begun the pulse rate was 144, respiration 36, and blood pressure 110 systolic and 74 diastolic.

"The blood pressure altered very little until the *ductus arteriosus* was ligatured, when there was a rise of 20 millimetres of mercury. The readings at the end of the operation were: pulse rate, 156; respiration, 36; blood pressure, 138 systolic and 100 diastolic."

Dr. Brown's blood pressure readings do not show the low diastolic figure which is characteristic of the condition and which Dr. Flaum and I both found. I discussed this with Dr. Brown, and he explained that his diastolic figure was taken at the point where a slight alteration of the sound occurred and not at its disappearance.

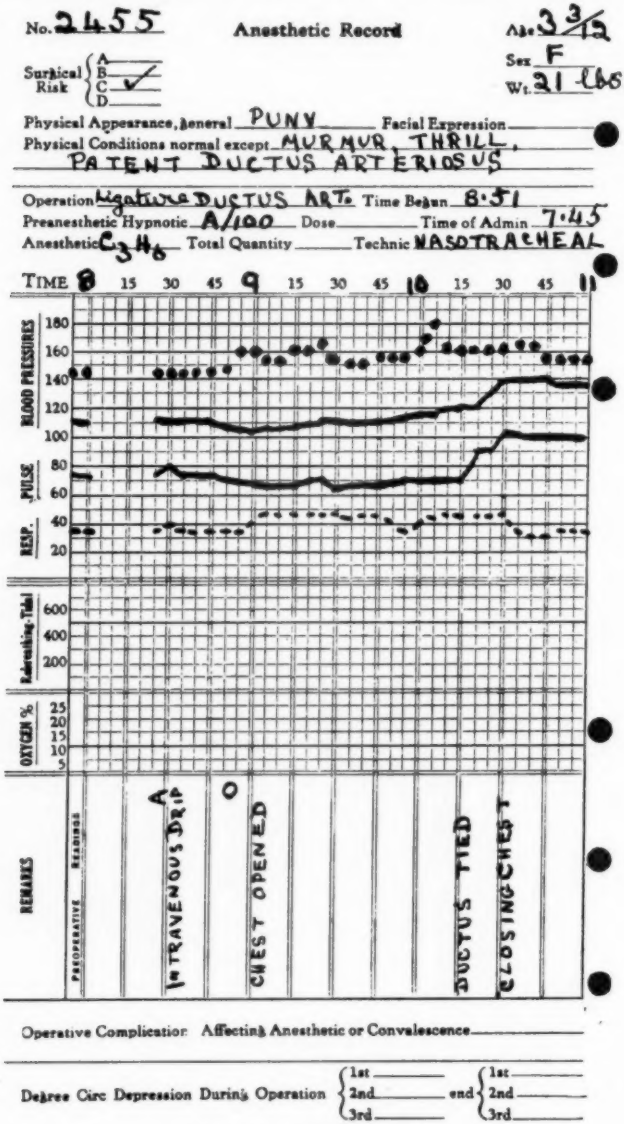
A pint of blood having been secured from the father, a transfusion was commenced by inserting a cannula into the internal saphenous vein in the region of the internal malleolus. This was by way of a precautionary measure and was continued throughout the operation. The child was placed on her back with the left arm extended up alongside the head and a small sandbag beneath the left shoulder.

A transverse incision slightly concave upwards was made in the region of the second left intercostal space, extending from the sternum to the axilla. The chest was opened through the second left intercostal space and after division of the second and third costal cartilages a self-retaining rib retractor was inserted and an excellent exposure was obtained.

The phrenic and vagus nerves were easily identified, and an incision was made in the mediastinal pleura approximately 1·5 centimetres posterior to the phrenic nerve. The incision extended from the root of the lung in an upward direction and parallel to the phrenic nerve. The pleura was dissected up and the interval between the arch of the aorta and the pulmonary artery was sought by blunt dissection with scissors and cotton wool swabs on holders.

A structure thought to be the ductus was separated and a ligature carrier was placed under it. On applying pressure to this structure the thrill did not disappear, so a further search was carried out. The vagus was picked up and the recurrent laryngeal nerve was identified hooking round a large structure which had been noted previously and was then thought to be the left pulmonary artery. Further examination proved this to be a large *ductus arteriosus* which entered the aorta at a very acute angle just distal to a point opposite the left subclavian artery. Blunt dissection by means of curved scissors was commenced on the medial side of the ductus, the dissection keeping close up to the aorta. The tunnelling beneath the adventitia of the aorta, as advised by A. S. W. Touroff,[2] was attempted, but was not successful in my hands. A little troublesome bleeding occurred whilst dissecting on the medial side of the ductus. It was brisk and appeared venous, but fortunately was controlled by pressure. Its origin was obscure, but it did not appear to be from a tear in the ductus. Dissection on this side of the ductus was discontinued and the lateral aspect of the structure was now exposed by retracting the vagus and recurrent laryngeal nerves with a narrow ribbon retractor. A plane was located by means of dissecting scissors and this was further opened up by a cystic duct clamp which was eventually worked right round the duct. Pressure was

now brought to bear on the ductus by approximating the index finger to the clamp. This movement caused the murmur to disappear, and as there were no untoward effects on the patient, a double ligature of number 6 braided silk was gripped in the clamp and drawn


No. 2455
Anesthetic Record
Age 3 3/12
Sex F
Wt. 21 lbs.
Surgical Risk A B C ✓ D
Physical Appearance, General PUNY Facial Expression
Physical Conditions normal except MURMUR, THRILL, PATENT DUCTUS ARTERIOSUS
Operation Ligature DUCTUS ART. Time Began 8.51
Preanesthetic Hypnotic A/100 Dose Time of Admin 7.45
Anesthetic C3H6 Total Quantity Technic NASOTRACHEAL
TIME 8 15 30 45 9 15 30 45 10 15 30 45 11
BLOOD PRESSURES 180 160 140 120 100
PULSE 80 60
RESP. 40 20
Rebreathing Tidal 600 400 200
OXYGEN % 25 20 15 10 5
REMARKS
PREOPERATIVE READINGS
A
INTRAVENOUS DRIP
O
CHEST OPENED
DUCTUS TIED
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Operative Complication Affecting Anesthetic or Convalescence
Degree Circ Depression During Operation 1st 2nd 3rd end 1st 2nd 3rd

FIGURE II. Anæsthetic chart.

back beneath the ductus, which was approximately 7·0 millimetres wide and 8·0 millimetres long. Both ligatures were then tied. There was an immediate rise of blood pressure, as can be seen by the accompanying anæsthetic chart (see Figure II). No attempt was made to close the mediastinal pleura and the chest wall was sutured in layers without drainage. Dressings were strapped in position and the arm was bandaged to the side.

Post-Operative History.

The child stood the operation very well, and the intravenous blood drip was discontinued approximately four hours after completion of the operation. Over a period of six hours 300 cubic centimetres of blood were administered.

FIGURE III. Showing patient after operation.

The temperature was elevated for four to five days, but it subsided by lysis with the assistance of sulphapyridine. For several days after operation there was definite hoarseness of the voice, probably due to irritation by the endotracheal catheter, but perhaps contributed to by trauma of the left recurrent laryngeal nerve.

The patient sat in a chair on September 29, 1943, and was walking about on October 5, 1943. She was discharged from hospital on October 6, 1943, having been upset very little by the whole ordeal, and showing a slight gain in weight. One outstanding feature was that before operation the pulse rate was 120 or over, but on discharge it was under 90.

Her progress since operation has been very gratifying, her parents stating that marked improvement has occurred both mentally and physically (see Figure III).

Her pulse rate continues in the eighties and her weight continues to rise steadily. For the twelve months prior to operation she gained 12 ounces and since operation she has gained 2 pounds 11 ounces up till December 16, 1943.

The following is the post-operative report of Dr. Flaum: "General health and colour definitely improved. The heart action is less rapid than before and no thrill is palpable. The original systolic murmur has completely disappeared. There is a splitting of the first sound over the apex. Here, as well as over the entire cardiac area, a soft systolic murmur of blowing character is audible, being somewhat louder towards the base of the heart. To the right and left of the *manubrium sterni* and along the infraclavicular region another systolic murmur of different (scraping) character is audible, which is transmitted into the large peripheral arteries and can be heard along the descending aorta down to the lumbar region. A short interval between the first sound and this murmur distinguishes it from the first-mentioned murmur which fills the entire systole, and characterizes this second murmur as 'post-systolic'. Blood pressure in both arms equals 70 millimetres of mercury, systolic, and 50 millimetres, diastolic. The electrocardiogram shows no significant changes.

FIGURE IV. Showing X-ray appearances after operation.

"The findings at the second examination can only be tentatively interpreted. In my opinion the post-systolic murmur is due to a relative aortic stenosis caused by an increased amount of blood being forced through the comparatively narrow aorta. The

systolic murmur and splitting of the first sound at the apex might be due to a temporary imbalance between the right and left ventricle or to insufficient adaptation of the ventricles to their new reduced or increased tasks."

The following is Dr. B. C. Smeaton's post-operative report:

"The appearance after operation shows lessening of diameter in the waist of the heart and no pulmonary congestion." (See Figure IV.)

Acknowledgements.

In conclusion I should like to express my indebtedness to Sir Henry Newland for his able assistance and advice at the operation. Dr. Gilbert Brown gave a masterly anæsthetic, the child at no time giving any cause for concern. The success of the operation was in no small measure due to his skill and attention.

Dr. E. Flaum made the diagnosis, suggested the treatment, and provided the report of the pre-operative and post-operative cardiac findings.

Dr. B. C. Smeaton, radiologist, provided reports on X-ray films and screenings, whilst Mr. B. G. Compton, technician, was responsible for X-ray films and photographs.

The success of the undertaking was due to good team work, and to the above-mentioned gentlemen I record my grateful thanks.

References.

(1) Robert E. Gross: "Surgical Management of the Patent Ductus Arteriosus", *Annals of Surgery*, Volume cx, September, 1939, page 321.

(2) Arthur S. W. Touroff: "A Modified Technique of Surgical Ligation of Patent Ductus Arteriosus", *Surgery*, Volume xii, 1942, page 24.

Surgery in Other Countries.

[In this column will be published short résumés of articles likely to be of practical value from Journals published in other countries and not readily accessible to surgeons in Australia and New Zealand.]

SALINE SOLUTIONS FOR INTRAVENOUS INFUSION.

Engelhardt (Erlangen): *"Ist es zweckmässig einer Blutersatzflüssigkeit ein Kolloid zuzusetzen?"*, *Der Chirurg*, Volume xv, May, 1943.

W. Weichardt (Wiesbaden): *"Infusionen mit Blutsalzlösungen"*, *Der Chirurg*, Volume xiv, February, 1942.

Blood substitution fluids differ from blood in that their effect can be only mechanical and must be transitory, and in order to render the mechanical effect more lasting various high-molecular substances have been added to the fluids, often without consideration of the fact that their metabolism is only partial and their excretion difficult. In fact, the quality of retention of a fluid in the circulation for long periods has often been taken as the standard of its efficiency.

Many attempts have been made to find a fluid which will reach this standard with an additional idea that an increase in the viscosity of the fluid must be valuable. It has been overlooked that the prime function of the blood proteins lies in other directions, as, for instance, clotting; and that an artificial increase in the viscosity of an infusion fluid merely throws an unwanted strain on the circulation without the compensating advantages of the lost blood. It is the water content alone which supplies the needed circulatory support.

Lost blood volume is fully restored in the body by two methods: (*a*) by the freeing of the splenic reserves (splenic flow), and (*b*) by increased outflow from the organs, lymph paths and connective tissues (tissue flow). Engelhardt (*Archiv für Kreislauff*, volume unspecified) has experimentally determined the extent to which each of these factors contributes towards the reconstitution of blood volume. The splenic flow can be demonstrated twenty minutes after the withdrawal of blood; tissue flow in ninety minutes. Intravenous administration of 0·1 milligramme of suprarenin in the seventh hour of the experiment stopped the splenic flow, while the tissue flow was increased. Owing to its red cell content, which becomes richer as the spleen nears emptying, the splenic outflow is the more important, particularly after severe bleeding. Using Weichardt's "Tutofusin" as a substitution fluid, Engelhardt was able to establish the amount of it in the circulation and the time for which it remained there. He found that half of it remained after one and a half hours, and the final third remained for nearly five hours. After the addition of glycogen, however, some four-fifths of the solution remained in the circulation for five hours.

It is therefore undoubted that such colloid addition will produce the effect sought; but Engelhardt points out that the same end can be attained by such other methods as continuous "drip" infusions, and more particularly by subcutaneous and rectal infusion, the latter being in essence a physiological method of increasing the ordinary tissue flow. His argument is that if further support for the circulation beyond what is given by intravenous infusion is needed, it is more readily achieved by subcutaneous infusions of a suitable solution without the addition of colloids.

Weichardt's article is a reference to the solution originated by him and known as "Tutofusin". It is supplied in large ampoules, sterile, stable and ready for use. Its preparation requires strict bacteriological, chemical and physical control, and reactions occurring after the use of many solutions are due to faults in such control and not to the principle itself. For instance, a high calcium ion content may in some cases cause malaise, and chemists are inclined to lessen or omit these ions, disregarding the fact that their detoxicating and other effects are of great importance.

There are many products of incomplete metabolism circulating in the blood of an individual, any of whose specific systems has suffered serious damage. If by the infusion of a solution of pure serum salts circulatory conditions can be brought back to normal, the reserve blood in the depots can oxidize and neutralize many of these. Moreover, through the swift passage of the solution out into the tissues, many of such substances can be removed from vital to less vulnerable environment.

Loss of red cells in hæmorrhage is not the main factor in causing death. Patients with a chronic anæmia can carry on with their hæmoglobin reduced to 12%, while in acute hæmorrhage patients may die with a hæmoglobin value still at 60%. Replacement of fluid is the primary necessity, and in the absence of blood "Tutofusin" may prove of

very great value. Its detoxicating effect has also proved valuable in intoxications in which hæmorrhage has played no part. Attempts to improve on it by the addition of colloids have not proved successful; and, indeed, until the process of metabolism and excretion of such substances is better understood, it is probably wiser that they should not be added.

ARTHUR E. BROWN.

NARCOSIS PRODUCED BY INTRAMUSCULAR INJECTION OF HEXENALE.

I. G. Sinichenko: "On the Intramuscular Narcosis with Hexenale", *Khirurgiya*, Number 1, 1943, page 25.

HEXENALE has been employed intramuscularly since October, 1941. One cubic centimetre of morphine in a 1·0% solution is administered subcutaneously to the patient. This is followed in fifteen to twenty minutes by an intramuscular injection into the buttocks of 20 cubic centimetres of a 10% solution of hexenale in distilled water. When the patient is asleep (that is, when his breathing is regular, when his eyes are closed, when he does not react to being called and when he snores) he is transferred into the operating theatre.

Hexenale, given in this way, was used as a general anæsthetic in 115 operative procedures. The operations were as follows: removal of foreign bodies from pelvis and lower limbs, 50 cases; amputations, 20; appendicectomies and herniotomies, 3; resection of stomach, 2; resection of ribs, 3; trephining of skull, 1.

Patients who were debilitated from loss of blood, transport or prolonged suppuration, slept immediately after the hexenale injection was given. Ten to fifteen minutes later the operation was performed. As a rule, sleep supervened without preliminary excitement.

Three stages are described in the literature: sleep, anæsthesia, post-anæsthetic sleep. On rare occasions sleep was preceded by a slight short excitement. In twelve cases the anæsthesia was not complete. No disturbance of blood pressure was detected. On neurological examination the Babinski and Oppenheim reflexes were present, which proves that hexenale acts on the cerebral cortex.

The stage of deep anæsthesia lasted long enough to allow any operative procedure to be carried out. Sleep continued after the operation for periods of from two hours up to twelve to fourteen hours and even longer. Patients frequently woke up and went to sleep again. Unpleasant sequelæ, like headache, nausea, vomiting, vertigo, were not noticed. The patients did not recollect anything from the time of hexenale administration.

The author came to the following conclusions:

1. Anæsthesia produced by the intramuscular injection of hexenale is technically easy; the drug can be administered by the sister under the supervision of the medical attendant.

2. Hexenale anæsthesia can be used in a variety of operative procedures.

3. Protracted suppurative conditions do not serve as contraindications for the intramuscular use of hexenale.

4. Fewer complications have occurred during sleep, during anæsthesia and in the post-anæsthesic period with this anæsthetic than with the common types of anæsthetic agent.

5. The intramuscular injection of hexenale can be recommended as an excellent method for the production of general anæsthesia.

A. S. MARSHALL.

THE TREATMENT OF HICCUP.

Weber: "*Zur Behandlung des Singultus*", *Zentralblatt für Chirurgie*, May, 1943.

THE article deals with cases of severe persistent post-operative hiccup which are not evidently dependent on a local inflammatory cause. Two cases are quoted in recent army work, and one earlier case.

The first case was that of a man, aged forty-five years, from whom 50 centimetres of colon had been removed on account of increasing obstruction. Shortly after the restoration of bowel function, hiccup set in. Thinking to neutralize some local factor, the author performed colostomy of the ascending colon. Everything inside the abdomen seemed to be normal at the operation, but the hiccup continued unchecked. Treatment instituted then consisted of repeated withdrawals of small quantities of blood, associated with massive infusions of "Tutofusin" and glucose, given twice daily. The hiccup ceased on the tenth day.

The second case was that of a Hungarian officer, aged thirty-four years, who was admitted to hospital with severe wounds of both legs due to a mine explosion,

and whose right leg was amputated below the knee owing to gangrene. In the four following days he was feverish, and his general condition deteriorated; he became jaundiced and developed tenderness below the right costal margin. The liver was palpable a hand's breadth below the rib margin, and the whole abdomen was distended. Persistent hiccup developed, and the administration of atropine preparations brought only slight and transitory relief. Then the administration of fluid was started, two to three litres of "Tutofusin" being given daily, at first intravenously, then by rectal and subcutaneous routes. In this case no withdrawal of blood was undertaken, as the patient was considered to be too weak and emaciated. With the subsidence of the fever and other symptoms, the infusions were interrupted, but after a few days' interval hiccup, fever and jaundice reappeared and massive infusions were restarted. After a further week of this treatment all symptoms disappeared.

In this case the hiccup, lasting for three weeks, and associated with fever, icterus and a generally menacing condition, seems to have been evidently based on some toxic irritation of the diaphragm. The liver infection of general hepatitis type may well have been due to septic emboli from thrombosed veins in the leg; but whether the diaphragmatic irritation arose directly from the subjacent liver or by a hæmatogenous route as a sequel to the liver damage was left undecided.

Both these patients were treated after a method which Weber first tried in a similar case some ten years previously. This was in a man, aged fifty years, who had a gangrenous cholecystitis, with a solitary stone the size of a walnut, and an associated pancreatitis. Owing to technical difficulties, a gauze tampon was put into the wound alongside the rubber drain. In its early stages the post-operative course gave rise to no anxiety, but then hiccup started which was not influenced by any of the remedies tried, nor even by infiltration of both phrenic nerves with "Novocain". Slight jaundice developed. There was no distension, and, on removal of the gauze pack, no discharge. The patient's condition remained tolerably good, although he was quite unable to take any nourishment. A consultant, two weeks after the operation, held that there must be a local cause for the hiccup, and the operation scar was excised. Although no clarifying factor was found when this was done, the hiccup stopped immediately, but in half an hour's time it recurred as vigorously as ever. Ten more days of general treatment brought no relief, and the prognosis was considered to be grave. Toxic liver damage was then suspected, and 40 cubic centimetres of blood were withdrawn for blood urea estimation. The blood urea content was found to be 300 milligrammes per 100 cubic centimetres.

Following the principles successfully applied in analogous cases of uræmia and eclampsia, blood was now withdrawn therapeutically, almost a litre being taken off, while the circulation was supported by an infusion of glucose. The hiccup ceased immediately, and the patient fell asleep, for the first time for three weeks. The next evening a slight attack of hiccup was brought to a prompt ending by a further withdrawal of blood; and on the two following evenings decreased amounts of blood were taken off and increasing amounts of glucose saline were given. There was no further trouble with hiccup, and complete recovery was swift. The rationale of this treatment is withdrawal of blood and toxic products and further flushing out of toxic products by large doses of saline infusions.

In the two army cases quoted it is probable that a high degree of intoxication originating in the kidneys and liver was the causative factor in producing the hiccup, and treatment on the same principles was effective.

ARTHUR E. BROWN.

Reviews.

The Principles and Practice of War Surgery. By J. TRUETA, M.D.; 1943. London: Hamish Hamilton Medical Books Limited, in conjunction with William Heinemann Medical Books Limited. 9″ × 6″, pp. 407, with 136 illustrations. Price: 42s. sterling.

THE name of Dr. Trueta has been so intimately associated with the surgery of war that a work entitled "The Principles and Practice of War Surgery" written by him will, in these times, be read with great interest. It is mainly concerned with the biological method of treatment of wounds and fractures. The basis of the book is, as one would expect, the experience of the author in the Spanish Civil War. To this experience, which has been amplified by discussions on the theoretical basis of the author's treatment of war wounds, is added the fruits of further work in war surgery gathered from the treatment of wounded in England since 1939.

The main theme of the book is detailed methods and principles involved in wound excision, the complete encasement of the wounded limb in plaster, and the preparation

of plaster casts, with illustrations to show the exact shape and size of all plaster patterns and the method of applying them to different parts of the body. Included in the book are chapters on shock, transfusion, aerobic and anaerobic infections (including gas gangrene and tetanus), chemotherapy, antisepsis, anæsthesia, skin grafting, amputation and the treatment of burns. The book reflects much credit on its publishers.

Regional Analgesia for Intra-Abdominal Surgery. By NORMAN R. JAMES, L.R.C.P. & S., D.A.; 1943. London: J. and A. Churchill Limited. 7¼" × 4¾", pp. 57, with 27 illustrations. Price: 6s. sterling.

THIS small book of Normal R. James is an excellent contribution to regional anæsthesia. It is a summary of the most satisfactory methods of applying this form of anæsthesia to intraabdominal surgery. It is concise and the methods described can be applied under all conditions.

The author has gone to considerable trouble to disprove an old theory that English-speaking people are unsuitable for any anæsthesia other than general. The most important deduction from the book is the fact that regional anæsthesia minimizes to the greatest degree possible post-operative and operative shock, and yet has also great value in combating shock from trauma, particularly to abdominal viscera. The value of this is seen in the application of regional anæsthesia to war surgery.

The small chapter on the intravenous use of "Omnopon" and morphine is of particular interest. The importance of preliminary narcosis in the success of a local anæsthetic has always been appreciated, but the difficulty has been in determining the actual dosage required by each patient.

This publication is very opportune and can be recommended to both the surgeon and the anæsthetist.

Fractures and Joint Injuries. By R. WATSON-JONES, B.Sc., M.Ch. (Orth.), F.R.C.S., Volume I, Third Edition, 1943. Edinburgh: E. and S. Livingstone. Pp. 420, with 608 illustrations. Price: 75s. net per set of two volumes.

THE first edition of Watson-Jones's book established for itself a most valuable reputation. The third edition can only enhance it. The addition of many illustrations has caused the author to divide the work into two volumes.

Volume I is divided into three parts. Part I deals with the principles of fracture treatment, Part II deals with pathological and birth fractures, and Part III with injuries of the trunk and head. The author throughout the whole book gives the widest interpretation to its title.

The work is illustrated very fully and has many colour plates of rare merit and inestimable value in the making of memory impressions. As in previous editions, the author has made use of the telling method of overlapping X-ray pictures with printed comment. This is a particularly ingenious method of stressing points in the diagnosis of fractures.

The part of the book devoted to the principles of fracture treatment is an exposition of such fundamental common sense and sound principle that it is in itself a worthwhile work. The preliminary discussion of repair of fractures is particularly well done. The section on avascular bone necrosis is instructive and carries its warning in relation to the indiscriminate nailing of fractures of the femoral neck. It is interesting to note the identification between avascular necrosis and Legg-Perthes's disease.

The chapter on reduction and immobilization of fractures carries useful hints and warnings. It should be always at hand in any hospital. It ends with a detailed account of theatre technique required for open reduction. Great attention is given to the no-touch technique. It may be commented that in view of full research of the source of infection in theatres, scepticism of the no-touch technique may be created by seeing an inexpert team fumbling clumsily with instruments and so increasing trauma to tissue and the length of exposure of wound to atmosphere. The stress given therefore appears to lack a sense of proportion. Such techniques are for the very expert and cannot be applied with advantage by every surgeon who has to operate on a bone, and today they are many.

The chapter on open and infected fractures and war wounds is of great value at this time. It is enriched by the experience of the author in this war and graphically illustrated by many colour plates. He expounds and insists upon the general principles of excision, open drainage and immobilization—sound principles until perchance the use of penicillin opens a better way to earlier cure.

There is a good chapter on spinal injuries, and the discussion of neurological aspects is well done. The chapter on spine leads the author into the vexed questions of low back strain and sciatica. They are discussed and classified with a proper lack of dogmatism. The intervertebral disc syndrome is discussed, though anyone who has

experience of the simplicity of expert operation and the immediate relief of pain and rapid convalescence, would criticize the author's pre-operative criteria, the operation and the convalescence he describes.

The author's style is exceptionally easy and conversational. One may open the book to study a particular section and can hardly help just reading on. To make such valuable knowledge so readily assimilable is to make a great contribution to surgical teaching.

The Biologic Fundamentals of Radiation Therapy. By FRIEDRICH P. ELLINGER, M.D.; 1941. New York: Elsevier Publishing Company, Incorporated. Pp. 376, with 79 figures. 9″ × 5½″. Price: $5.00.

THIS book is an English translation, dated 1940, of a German work published in 1935. The first part of the book deals with the effects of X and γ radiations on normal tissues, and a dozen chapters deal with the various systems. This part concludes with chapters on the role of radiation in the treatment of the inflammations, the granulomata and innocent and malignant neoplasms.

Individually these sections leave dissatisfaction with the inadequate discussion of radiation effects as seen in clinical practice. As example the chapter on the respiratory tract may be cited. The effects on the larynx are dismissed in half a page, and the reader is told of the results of tissue dosage of "550" and "650*r*". But no mention is made of the effects on the larynx subsequent to treatment with heavy γ ray dosage as applied in, for example, Harmer's radium technique, nor of the effects of high tissue dosage which is applied in treatment of carcinomata of the region, as in Coutard's technique. In the following subsection on lungs a few lines and a footnote are devoted to pulmonary fibrosis following post-operative treatment of carcinoma of the breast, but there is no reference to the effects on the lung of the differing tissue doses required in the treatment of, for example, pulmonary or mediastinal neoplasms, of Hodgkin's disease and of early cases of bronchiectasis.

However, good chapters on the radiation effects on blood and blood chemistry are included. Many of the recommendations for dosage in the sections on neoplasms cannot be accepted. Statements of radium dosage throughout the book are usually meaningless for lack of precise data. Similarly much loose statement of X-ray dosage occurs—it is particularly irritating to have free-in-air dosage stated without a mention of field measurements, let alone other relevant factors.

The other major part of the book is devoted to ultra-violet light and full consideration is given to this subject. The author has produced his best work in this section. The section on infra-red radiation is small in comparison. Sections on effects of visible light and chapters on general radiation biology and therapy conclude the volume.

The great number of footnotes contain much material which should be textual, and do not help the reader.

The volume has a very full bibliography, which is extensively quoted in the text. The author must be commended for summarizing much of the very diffuse literature which has grown around this subject. The book can be of use only to the radiation specialist. The preface writer recommends it also to the general clinician and the medical student, but it is not fit material for such people.

Medical Clinics on Bone Diseases. By I. SNAPPER; 1943. United States of America: Interscience Publications, Incorporated, New York. Australia: W. Ramsay (Surgical) Proprietary, Limited, Melbourne; The Graham Book Company, Sydney; Angus and Robertson, Limited, Sydney. Pp. 234, with 30 X-ray plates. 11″ × 8¼″. Price: $10.75.

THIS publication is a contribution of some value to medical literature. The quality of the publisher's work is the immediately striking feature; the book is beautifully printed and set up with a large number of full plates of radiographic and photomicrographic appearances. These plates are on glossy surface and in themselves form a most beautiful and valuable atlas of the conditions discussed.

The conditions Snapper deals with *in extenso* are: (*a*) Recklinghausen's disease and hyperparathyreoidism, (*b*) hyperplasia of the parathyreoids secondary to other diseases, (*c*) avitaminosis *D*, (*d*) Paget's disease, (*e*) lipoid granulomatosis of bone, (*f*) Gaucher's disease, (*g*) multiple myeloma.

Nearly half the book is devoted to Recklinghausen's disease and hyperparathyreoidism. This section constitutes the most complete exposition of this subject. The author's scientific discussion is full and complete, his examples of all types are illuminating and his bibliography is extensive. On the illustrative effects of both X-ray pictures and photomicrographs it would be difficult to improve. If criticism were to be

offered it would be that the radiographic examples are all of well established and typical appearances. The value of the work could be enhanced by inclusion of some early and disputable X-ray appearances. Such are the things that cause real trouble to the experienced clinician. Snapper has drawn widely for his examples of these bone diseases, and the fruitful field of advanced pathology that lay to his hands in China has been very fully used. This is particularly apparent in the section on avitaminosis *D*.

In this section he discusses jointly the bone changes in fœtal rickets, infantile rickets, late rickets and osteomalacia. He points out that avitaminosis *D* leads to different bone reactions at different periods of life. In North China, where there is a great poverty of calcium in the staple adult diet, he had ample experience of osteomalacia.

The section on Paget's disease is well done, possible ætiology and usual methods of treatment being discussed.

The discussion of lipoid diseases is also comprehensive. The author lays emphasis on the fact that lipoid granulomatosis of bone may occur apart from the complete syndrome of the Hand-Schüller-Christian disease and has to be distinguished from Recklinghausen's disease.

The final chapter on multiple myeloma is an excellent compendium of knowledge, and is beautifully illustrated.

A work of this nature is concerned with conditions which are in ordinary practice rare. It therefore serves a most useful function in that so readily to hand we have a complete exposition of each disease discussed. The book should be owned by every surgical teacher and radiologist. There is a very full author and subject index.

The Arthropathies: A Handbook of Roentgen Diagnosis. By ALFRED A. DE LORIMIER, A.B., M.A., M.D.; 1943. Chicago: The Year Book Publishers, Incorporated. Pp. 319, with 678 figures. 8″ × 5¼″. Price: $5.50.

"THE ARTHROPATHIES" is the title of a book written by Alfred A. de Lorimier. The basis of the book is lectures given by the author during recent years to officers at the Army Medical School, Washington, and at the Army School of Roentgenology, Memphis, United States of America. It is a handbook of X-ray diagnosis of diseases and abnormalities of joints.

In the description of the various arthropathies, set out categorically, are: the synonyms of the disease, the Röntgen criteria in the early and late stages, the corroborative Röntgen criteria, the incidents, the histories, the physical and laboratory findings—all followed by a bibliography of that particular joint condition and illustrated by a set of characteristic X-ray photographs.

The correlation of X-ray, clinical and laboratory data and the uniform categorical layout of the subject-matter are valuable aids to differential diagnosis.

These essential principles which enable soft as well as osseous tissue to be Röntgenographically visualized are described. The anatomy of various joints is pictured in terms of X-ray shadows. Normal development and malformation are illustrated by a series of excellent X-ray pictures. Every form of joint disease is fully described, and its various phases are illustrated with very clear radiographs. The book contains over 600 well produced X-ray pictures.

The book is one which will be found valuable not only to the X-ray specialist but to the surgeon and to the physician.

Proceedings of the Royal Australasian College of Surgeons.

MEETING IN MELBOURNE.

A MEETING of the Royal Australasian College of Surgeons was held at the College Headquarters in Melbourne on Friday, May 26, 1944.

President's Address.

The President, Sir Alan Newton, delivered the following address.

It is customary for the President, at meetings at which the Syme Oration is delivered, to give a brief address dealing with some aspect of the activities of the College. Owing to conditions imposed by the outbreak of war, five years have elapsed since the last oration was given by Sir Alfred Webb Johnson, now President of the Royal College

of Surgeons of England, and it seems appropriate for me to refer to some of the actions taken by the College during this time to help the national effort.

One of the first of these was the provision of accommodation in this building, rent free, for the Central Administration of the Australian Red Cross Society. The Council felt that it was a privilege to be able to help the society in this way, and desires me, now that the society is about to move to its new headquarters, to thank it for the care it has taken of the building. The joint occupancy has been most harmonious. The Council and Fellows of the College are more than repaid for their action in making this space available by the gracious and generous acknowledgement made by Her Excellency Lady Gowrie, in a farewell message to the Red Cross Society in this hall a few days ago. The space vacated by the society will be used to provide for a much needed expansion of the library.

Another notable action was taken in September, 1939, when the College, in conjunction with the Royal Australasian College of Physicians, inaugurated a plan to supplement the income of consultants and specialists who gave up their practices in order to join the Navy, Army or Air Force. As a result of the voluntary payment of levies made upon an agreed scale, the claims of all beneficiaries on service have been met in the past and will be met in the future. It can justly be claimed that this achievement does honour to all those who took part in it. In addition the College has made grants from its own funds for the purpose of financing research work upon problems of interest to the medical services of the fighting forces.

The library of the College, since the outbreak of war, has been made available to all members of the profession and has been used extensively by serving officers. Photostats of articles, reprints and translations have been supplied in large numbers to men serving in the field and in base hospitals, both of our own forces and those of our allies. Every effort has been made to keep them fully informed of recent advances in surgical knowledge, and it is of interest to note, in this connexion, that arrangements have been made to receive tables of contents of recently published German journals, so that photostats can be obtained of selected articles. Articles are also abstracted from the Russian journal *Khirurgiya*, which is received in exchange for our own journal. In addition, numerous valuable contributions to our knowledge of war surgery, written by our own Fellows, have appeared in THE AUSTRALIAN AND NEW ZEALAND JOURNAL OF SURGERY. All this illustrates the well-known fact that surgery knows no national boundaries.

These are some of the more important steps which have been taken by the College during the last four years. It will be apparent that, in addition to the magnificent surgical service which has been given by very many individual Fellows, the College itself, as a corporate body, has made an important contribution to the war effort.

I must mention one additional action which is of value to this country for all time. This is the purchase by the College of the late Dr. Cowlishaw's library of old medical books. This is undoubtedly the finest collection in the southern hemisphere and one of the best private collections of its kind in the world. It is a matter for congratulation that this magnificent library of more than 3,000 books, which is the result of a lifetime's work by Dr. Cowlishaw, will remain for ever in this country. The historical section of our Gordon Craig Library has also been enriched by old books given to it by the Royal College of Surgeons of England, which has done so much to help our young college.

So much for what has been done in the past. Now let us turn to the task which lies before the College in the future, particularly in the years immediately following the end of this war. The chief problem during this time will be that of the post-graduate education of men who wish to become specialists in surgery and whose training in this direction has been interrupted by military service. The main purpose of the College is to arrange for adequate post-graduate training in surgery, and it has informed the Commonwealth Government that it is prepared to undertake this activity in Australia in order to meet the needs of those men now on service who desire to undergo this training in surgery and the allied specialties. It is in a peculiarly advantageous position to do this work for many reasons. Not the least of these is the fact that the income from that part of the Gordon Craig Endowment Fund which was set aside before the war to give financial assistance to young men undergoing a higher surgical training, has been accumulated during the past five years and now amounts to a substantial sum. A conference is to be held at an early date with representatives of the Council of the Royal Australasian College of Physicians in order to explore the possibility of close collaboration between the two Colleges in this work.

I must emphasize the fact that, in so far as the College is concerned, its activities will be confined to those men who wish to undergo advanced training in surgery; in other words, to a small percentage of demobilized medical officers. The need of the vast majority of these men will be for more general training in all those aspects of medical work which are necessary for general practice. This need will be met by the efficient

post-graduate committees in the various States which were established for this purpose at the end of the last war. It is obviously necessary to establish harmonious relationships between the different bodies concerned with the various aspects of post-graduate education as some overlapping must occur, but there should be little difficulty in achieving this aim.

Nor must it be thought that the College is in active competition with universities in the field of post-graduate surgical training. I agree with the view recently expressed in a report written by the Vice-Chancellor of the University of Melbourne with special reference to advanced technical training in engineering. He points out that it is the duty of a university to give training based upon a background and, in order to have time to do this, he suggests that it should make plans to "slough off" some of its lower layers by arranging for preliminary education in junior colleges and also some of its higher layers by arranging for suitable outside bodies to undertake advanced technical post-graduate instruction. This is a reasonable and rational viewpoint which should meet with general approval. It is the duty of a university to produce men who have undergone a sound education not restricted to purely didactic teaching, leaving other bodies, such as this College, to deal with advanced special types of purely technical post-graduate instruction, in close cooperation with the university itself. The value of such an arrangement in the immediate post-war period, when the universities will be overcrowded with undergraduates, will be obvious to those of you who witnessed a similar state of affairs at the end of the last war.

I must emphasize the importance of active cooperation between the College and the Australian universities. All are striving to achieve a common aim—the production of highly trained and efficient medical men. It follows that each must be vitally concerned with the work done by the others. This fact emboldens me to refer to the important question which relates immediately to the universities, but will concern this College at a later date—namely, the selection of medical students. The Commonwealth Government has introduced subsidies to enable students, who otherwise could not afford it, to undergo training at the universities. It has also established quotas of students to be admitted to university courses. These actions are wise and proper. All will agree that admission to a university should not be restricted to members of any one class in the community. But there is some anxiety about the type of student who is being selected to fill the quota particularly in so far as the medical course is concerned. It is understandable that many boys leaving school who would be suitable in every respect to undergo medical training elect at present to enter the services, with the result that the quota is filled by the admission of some less well qualified, when measured by all the standards desirable in members of this profession. The obvious remedy is to fill the quotas as far as possible by men who have given three or four years' military service and who had completed portion of the medical course or had matriculated and intended to become doctors before enlistment. The consent of the services concerned for their release must be obtained, but, in view of the fact that the total number is comparatively insignificant and that no loss of total manpower would be involved because the numbers in reserved quotas would remain unchanged, this should be readily forthcoming in the majority of instances.

It is true that such men may apply to enter the university at present, but in actual fact few men of good quality will take the initiative in making such an application. They should be directed to do so by the proper authority. Certain difficulties in carrying this suggestion into effect are apparent. For example, it would be necessary to obtain from schools and universities lists of names of men who had intended to enter the medical course or who had left it in order to enlist. But these difficulties are by no means insuperable, and it is to be hoped that the Universities Commission will overcome them. It is of the first importance to the community that future doctors should be of the best possible quality, and the vast majority of prospective medical students of this quality are at present in the services. They should be returned to the universities before they grow too old to be able to resume academic work with efficiency.

May I, in conclusion, express the hope that before very long we shall be once again at peace and be able to put into operation the plans for the improvement of surgical education which were drawn up by the College before the war and which will be so valuable in the post-war period.

George Adlington Syme Oration.

The eighth George Adlington Syme Oration was delivered by Professor V. M. Trikojus on "Recent Investigations Concerning the Biochemistry of the Thyreoid Gland".

Admission of New Fellows.

The following were formally admitted to Fellowship of the College: John Berchmans Devine, Benjamin Keith Rank, John Clark Spencer.

Ryan Scholarships in Surgery.

Gold medals for the Michael and J. P. Ryan Scholarships in Surgery which had been won during the last three years, were presented by the President to the following: Dr. Lorna Sisely, Dr. James Macky, Dr. Geoffrey Ryan (Michael Ryan Scholarships in Surgery); Dr. Douglas Duffy, Dr. Sydney Rubbo, Dr. George Bedbrook, Dr. John Hurley (J. P. Ryan Scholarships in Surgery).

COUNCIL MEETING.

The following matters arising out of the meeting of the Council held on Saturday, May 27, 1944, are published for the information of Fellows.

Resignation from the Council.

It is with deep regret that the Council wishes to report the resignation of A. L. Kenny as a member of the Council.

The Council passed a resolution thanking A. L. Kenny for his long and devoted service to the College and expressing great regret at his resignation from the Council.

Election of Council.

Eight nominations were received for six vacancies on the Council. As the result of the ballot, the following Fellows were elected to the Council: E. D. Ahern, George Bell, W. A. Hailes, T. E. Victor Hurley, Sir Henry Newland, Balcombe Quick.

Appointment of State and Dominion Committees.

The following appointments were made:

New Zealand: Frank Macky, D. S. Wylie, David Whyte, P. Stanley Foster, J. Leslie Will, J. A. Jenkins.

New South Wales: A. J. Aspinall, V. M. Coppleson, B. T. Edye, E. M. Fisher (deputy for I. Douglas Miller), T. M. Furber (deputy for F. Brown Craig), J. W. S. Laidley, T. W. Lipscomb (deputy for A. M. McIntosh).

Queensland: Hedley J. Brown, J. C. Hemsley, A. E. Lee, J. J. Power, A. D. D. Pye, Neville G. Sutton.

South Australia: R. M. Glynn, H. Gilbert (deputy for L. A. Wilson), I. B. Jose, L. C. E. Lindon, R. E. Magarey (deputy for B. H. Swift), P. S. Messent.

Tasmania: F. W. Fay, J. Bruce Hamilton, H. W. Sweetnam (deputy for D. W. L. Parker).

Victoria: A. Fay Maclure, J. Newman Morris, Henry Searby, John H. Shaw, C. Gordon Shaw, G. R. A. Syme, B. T. Zwar.

Western Australia: J. P. Ainslie (deputy for F. J. Clark), H. B. Gill, D. D. Paton.

Admission of New Fellows.

The following Fellows were admitted by the Council:

Victoria (General Surgery): James Grayton Brown, Alfred Murray Clarke, Arthur Ormond Green, John Isaac Hayward.

New Zealand (Laryngo-Otology): Malcolm Robertson.

HYDATID REGISTRY.

THE following is the annual report of the Hydatid Registry of the Royal Australasian College of Surgeons for the year ending December 31, 1943, submitted by the Registrar-in-Chief, Sir Louis Barnett:

Mainly owing to increasing wartime difficulties in case recording and partly perhaps due to some expected diminution in hydatid incidence, the number of records added to the registry, amounting to 58, shows a very definite drop as compared with pre-war years.

The records, accompanied by their précis cards, now number 1,715 and are tabulated as follows:

Region Affected.	Australian Cases.		New Zealand Cases.	
Liver	505		460	
Abdominal and pelvic, peritoneal (secondary)	69		55	
	—	574	—	515
Lung		196		216
Muscle and fascia		35		46
Bone	13		10	
Spine	16		6	
	—	29	—	16
Kidney		14		24
Spleen		14		7
Brain		6		9
Heart		3		2
Thyreoid		—		2
Breast		1		2
Pancreas		1		1
Parotid		1		—
Prostate		—		1
Total		874		841

Total for Australia and New Zealand: 1,715.

An analysis of these records reveals amongst other things:

1. The location of cysts in the lungs in Australasian cases appears to be about twice as frequent as in the cases listed in overseas literature.

2. In about a third of the patients cysts occur in more than one region of the body at the same time; especially notable are the liver and lung multiplicities.

3. With rare exceptions the commonly occurring peritoneal hydatids grouped under the caption "multiple abdominal and pelvic cysts" are instances of secondary cyst implantations resulting from a leakage from a primary liver cyst (or conceivably from a primary splenic or omental cyst).

4. This leakage from primary liver cysts has, in the great majority of cases, occurred in juveniles where the cyst is univesicular, thin-walled and at high intracystic tension. Traumatism from some external injury or from violent muscular effort no doubt explains the fissuring of the primary cyst, but the history of such a happening is often dubious or absolutely lacking, and the occurrence of a tell-tale urticaria or other evidence of anaphylaxis due to the absorption into the blood stream of antigens or toxins is more often than not non-existent or perhaps completely forgotten.

5. It is quite rare to find a juvenile cyst—that is, one that is univesicular and at high tension—in an adult, middle-aged or elderly person. The initial hydatid infection appears to be very largely limited to childhood, and the resulting cysts grow so slowly and quietly that in the majority of cases their presence is revealed only in adult life, sometimes indeed only in old age or on the autopsy table.

6. The obvious conclusion is that human susceptibility to hydatid infection is practically limited to a small number of children who are unfortunate enough to swallow the hydatid eggs distributed in the dust of dogs' droppings. Most children and almost all adults appear indeed to be immune to primary infection. Some of the many problems associated with hydatid immunity are receiving laboratory attention at the Otago Medical School, and the research technique has been facilitated by the discovery that mice formerly thought resistant to infection with hydatid ova can be rendered susceptible by appropriate preparation.

7. Errors in diagnosis still occur too commonly, due mainly to failure to sense the possibility, if not the probability, of a hydatid explanation of the clinical features. For example, thirty-two patients with hydatid cysts of the liver have been pre-operatively diagnosed as cholecystitis or/and gall stones and the manifestation of the cysts came as a surprise at operation.

To the hospital surgeons and their house surgeons, the medical superintendents and registrars in the various districts of Australia and New Zealand, and to the officers of the Gordon Craig Library staff, Miss N. C. Andrew and Miss A. Oldham, I offer, on behalf of the Royal Australasian College of Surgeons Hydatid Registry, cordial thanks for the valuable help given me during the year in the accumulation and filing of the records.

L. E. BARNETT,
Registrar-in-Chief, Hydatid Registry.